This project has received funding from the European Union's Horizon 2020 research & innovation programme under grant agreement n°815301.



# Deliverable D1.2
# Elicitation of Building-Users/Owners and RE Installers Needs Report

### Document Information

| | |
|---|---|
| Programme | Horizon 2020 – Competitive Low-Carbon Energy |
| Project acronym | RE-COGNITION |
| Grant agreement number | 815301 |
| WP/Task related | WP1 / T1.2 |
| Number of the Deliverable | D1.2 |
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| Number of pages | 68 pages |
| Status and Version | Version 1.0 |
| Confidentiality | CO Confidential |
| Contractual Date of Delivery to the EC: | 30th September 2019 |
| Actual Date of Delivery to the EC: | |

Reviewers:

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### Copyright



## Version history

| Version | Date | Author/Reviewer | Notes |
| --- | --- | --- | --- |
| 0.1 | 23/09/2019 | Hannah Berg<br>Mario Pansera | First Draft of the Deliverable |
| 0.2 | 26/09/2019 | | Revision of the Draft |
| 1.0 | 30/09/2019 | Hannah Berg<br>Mario Pansera | Final Revision and Consolidation |
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# Executive summary

The objective of this document is to design and implement a process of internal and external stakeholder engagement and participation based on the pillars of Responsible Research and Innovation (RRI). Effort will be made in creating a balanced group of building eco-systems' stakeholders and end-users on the basis of age, technology literacy and other criteria. Later-on, the extracted user requirements will be adopted for the development of the BE-PLATO solution. To this end, gender dimension of the users' requirements will be taken into account as well. During this task, the socio-technical issues associated to the technological solutions proposed by the project will be discussed and negotiated among a sample of end-users, researchers and external stakeholders. The project will identify which aspects of human sensory and behaviour should be taken into account when evaluating the system's performance (e.g. ease of use by everyone, physiological and psychological obtrusiveness levels due to vibrations or unwanted/ frequent system interactions/notifications etc). The outcome of the task will consist in a set of specifications that will be regularly revised and renegotiated as the project matures. The needs will be mainly grouped in two categories: human comfort and technical:

- The human factor needs will address the requirement for unobtrusive system operation within the urban environment. Initially a literature review will take place regarding the impact that electromechanical RES equipment has on the human factors and the associated tolerance levels depending on the application environment (office, residence, industry). The end-user group will provide input and validation on the findings of this study.

- The technical requirements study will investigate safety and security aspects regarding the equipment placement, operation limits, robustness against the elements as well as compliance with regulations regarding installation of equipment on built/urban environments. As an example, installation of PVs is subject to fire safety regulations and specific spaces on the roof must be empty for firemen access. This limits the solar energy harvesting capacity of a building but on the other hand highlights an advantage of BIPVs, which can be installed on building surfaces other than rooftops.

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# Notations, abbreviations and acronyms

Table 1 reports the list of abbreviations adopted in the entire document.

| | |
|---|---|
| AACU | Adsorption Air Conditioning Unit |
| ACC | Air Conditioning and Cooling |
| ACEME | Automated Cognitive Energy Management Engine |
| AHJ | Authority having Jurisdiction |
| BE-PLATO | Building Energy Plant planning Tool |
| BIPV | Building Integrated Photovoltaic |
| Cd | Cadmium |
| CdTe | Cadmium Telluride |
| CHP | Combined Heat and Power |
| CIGS | Copper Indium Gallium Selenide |
| CO | Carbon Monoxide |
| CrVI | Hexavalent Chromium |
| C-Si | Crystalline-Silicon |
| dB | Sound Decibel |
| DDoS | Distributed Denial of Service |
| DNO | Distribution Network Operators |
| DoD | Depth of Discharge |
| DRC | Democratice Republic of Congo |
| DSO | Distribution Systems Operator |
| EAFO | European Alternative Fuels Observatory |
| EEA | European Environment Agency |
| EESCP | Energy Expert Cyber Security Platforms |
| EMF | Electromagnetic Fields |
| EPRS | European Parliamentary Research Service |
| EV | Electric Vehicle |
| GDPR | General Data Protection Regulation |

| | |
|---|---|
| GHG | Greenhouse Gas |
| HF | Hydorgen Fluoride |
| Hg | Mercury |
| HSC | Hybrid Solar Cooling |
| ICT | Information and Communication Technology |
| iGateway | Information Gateway |
| IT | Information Technology |
| LCO | Lithium Colbalt Oxide |
| LFP | Lithium Iron Phospate |
| MCL | Maximum Contaminant Level |
| MCS | Microgeneration Scheme |
| NCA | Lithium Nickel Colbalt Aluminium Oxide |
| NMC | Lithium Nickel Manganese Colbalt Oxide |
| NO | Nitiric Oxide |
| $NO_X$ | Nitrogen Oxides |
| NSHEV | National Smoke and Heat Exhaust Ventilators |
| OTA | Over-the-Air |
| Pb | Lead |
| PBB | Polybrominated Biphenyls |
| PBDE | Polybrominated Diphenyl Ethers |
| PCM | Phase Change Materials |
| PHEV | Plug-in Hybrid Electric Vehicle |
| PV | Photovoltaic |
| RCRA | Federal Resource and Recovery Act |
| RECC | Renewable Energy Consumer Code |
| RES | Renewable Energy Resources |
| RET | Renewable Energy Storage |
| RoHS | Restriction of Hazardous Substances |
| RRI | Responsible Research and Innovation |
| Se | Selenium |
| $SO_2$ | Sulphuric Oxide |

| | |
|---|---|
| SWT | Small Wind Turbine |
| TCS | Thermo-chemical Storage |
| TES | Thermal Energy Storage |
| UoB | University of Bristol |
| V2G | Vehicle 2 Grid |
| WEEE | Waste Electrical and Electronic Equipment |
| WHO | World Health Organisation |

# 1 Public Engagement and Stakeholder Engagement Strategy

In this section we set out our plans to support the process of internal and external stakeholder engagement and participation based on the pillars of Responsible Research and Innovation (RRI).

**What is RRI?**

Responsible Research and Innovation is an approach that anticipates and assesses potential implications and societal expectations with regards to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation [1].

RRI recognizes a 'collective responsibility where funders, researchers, stakeholders and the public all have an important role to play. It includes, but goes beyond, considerations of risk and regulation [2].' As an EU funded project, Re-cognition has a responsibility to ensure that its work is in the public interest and creates value for society. Public Engagement is one of the main pillars of RRI, therefore Re-cognition also has a responsibility to incorporate Public Engagement approaches into the project.

**RRI, Stakeholder Engagement and Public Engagement**

Re-cognition implements a reflexive RRI approach, inviting partners to engage in an ongoing process of reflection and responsiveness through collaborative and creative discussion-based workshops. The University of Bristol (UoB) developed this approach on the Horizon 2020 PERFORM project, in which UoB ran RRI workshops for early career science researchers. This reflexive approach allows for a more holistic approach to enhance stakeholder engagement. For the purpose of this report we are taking the narrow definition of stakeholder engagement as engagement of organizations directly affecting or affected by the projects work. However, during the initial RRI workshop, held in July 2019 at the University of Bristol, we got Re-cognition partners to anticipate the future consequences that Re-cognition could have within society (i.e. decentralizing energy generation, possible of off-grid, remote living and political tension between countries due to reduced reliance on fossil fuels). Some of the resulting reflections were that Re-cognition technology will have far-reaching implications, that will indirectly impact many publics within a Re-cognition-utilizing society, a broader group of people than have been initially reported in the preliminary external stakeholder group (see Table 1). Therefore, we will employ public engagement to enhance the stakeholder engagement process. This will encourage a broader and more diverse range of voices into the conversation, encouraging conversations that are meaningfully two-way, participatory and authentic.

## RRI Workshops, Partner Reflection Sessions and Knowledge Sharing Workshops

UoB will organise and hold various RRI workshops, Partner Reflection Sessions and Knowledge Sharing Workshops with consortium members (Fig.1 shows the process and activities we will be implementing through the project). These sessions aim to achieve the following:

- To cultivate partners understanding of RRI and its relevance to the Re-cognition project
- To provide a space where partners can discuss, engage and respond to RRI issues that may arise throughout the project
- To encourage partners to be reflective around their involvement within the project

- To inspire and support partners to implement tangible actions that will align their input on the project with the values of RRI
- To support them in relation to their stakeholder and public engagement process

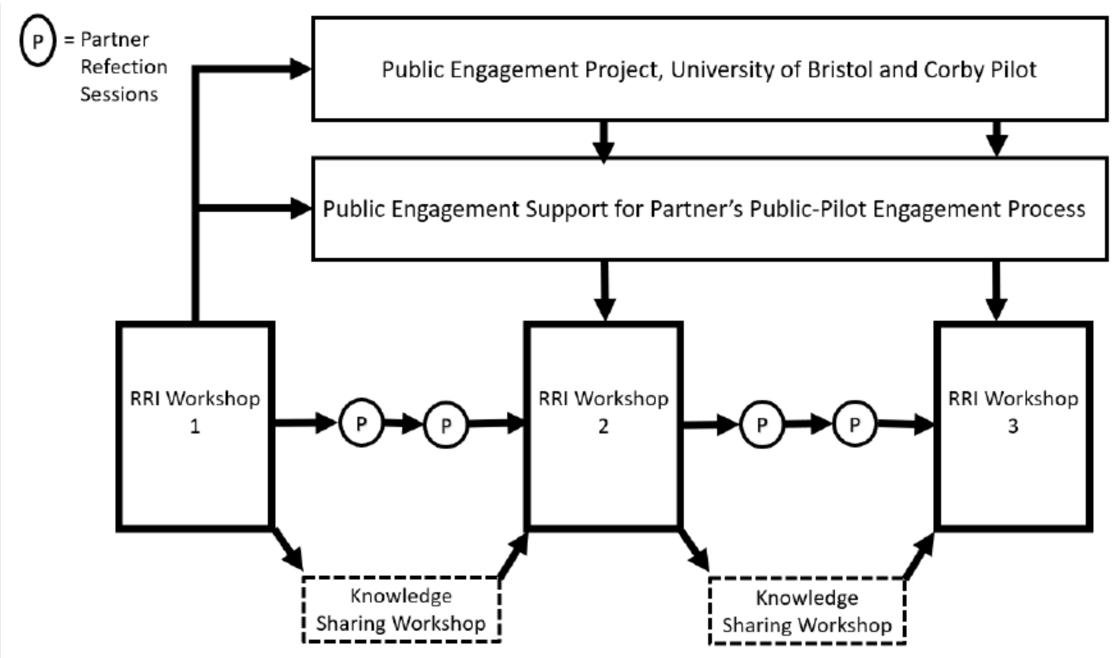


Figure 1 : Flow chart showing the process and activities involved in the Stakeholder and Public engagement strategy

## RRI Workshops

As this might be the first time that partners are leaning about RRI, these RRI workshops are an important opportunity to nurture their understanding of RRI and how it can be applied to the project. These workshops will be supportive and reflective environments, whereby attendees can ask questions and contemplate ideas. UoB will hold three annual workshops for consortium members; attendees will take part in a series of talks, participatory activities and reflective group discussions. The RRI workshops will be designed to enable attendees to:

- learn about established RRI framework (i.e. EPSRC Area Framework)
- gain perspectives on RRI in engineering by learning about other projects or research that have incorporated RRI their approach
- learn from experts in the field talking about RRI, data security, public engagement etc
- explore and reflect on their own personal and collective standpoint, and how this may affect their involvement within the project
- Anticipate potential positive and negative impacts (relating to health, environment and society) that might arise from the project
- Engage in challenges that require them to think and make decisions around risk, consequences and future thinking.

### Partner reflection sessions

Representatives from each partner will be asked to take part in partner reflection sessions via online video-calling platforms i.e. Skype, hosted by the UoB. These sessions will be focused around discussing some of the Re-cognition RRI themes that emerged in the initial RRI workshop held in July 2019, along with topics described in the T1.2 deliverable tasks (i.e. socio-technical issues, impacts on human sensory and behaviour, and human factor needs). The themes that will be discussed in these sessions will relate to the impact, implications and applications of this project's work. As such, part of these conversations will be around *who* the work may impact, helping to identify a wider range of stakeholders and publics. The sessions will encourage partners to identify tangible actions, many of which will be concerned with engaging with stakeholders and publics and ensuring that the project is responsive to those conversations. Partner representatives will be encouraged and supported to share these discussions and reflections with the rest of their teams. These sessions will occur frequently and will be scheduled for times when the outputs can optimally influence the project trajectories in order to complement project developments. This exercise will encourage partners to have a shared vision of what success of the project might look like, but also will allow for personal reflections of their involvement within the project and how they could align this with the values of RRI.

### Knowledge sharing workshops

A major element of RRI is building in reflective practice and knowledge sharing amongst project partners. Therefore, two project-wide Knowledge Sharing workshops will be held alongside consortium meetings. These workshops will focus on partners sharing their project-specific learning around RRI and how they have aligned this learning to their involvement on the project. It will also be a space for partners to collectively work through any concerns or issues that may have arisen through their RRI experiences and to also support one another in overcoming these issues. These sessions will encourage partners to share and explore best practise around maintaining a 'responsible' role within the project, upholding reflexive practise of RRI and reviewing and supporting on-going outputs from the stakeholder and public engagement process.

# 2 Public Engagement Strategy

The activities set out in the Public Engagement strategy will explore how long-term engagement, centred around RRI-focused discussions, will foster meaningful engagement between Re-cognition partners and the people living in and around Re-cognition pilot sites. The RRI-focused discussions that will feed into this public engagement project, will revolve around the RRI Recognition themes, however space will also be created for the group to discuss and reflect upon issues that they feel are important to them in relation to the project. The UoB will lead the Public engagement project with the pilot site Corby, working closely with Electric Corby. Alongside this project the UoB will support other partners to explore a similar public engagement approach with their pilots.

The aims of this public engagement activity are:

1) Establishing a trusting relationship with members of the public group and working with them over the project duration.
2) Holding workshops and discussions with this group to explore the RRI issues that relate to the Re-cognition project, along with topics described in the T1.2 deliverable tasks (i.e. socio-

technical issues, impacts on human sensory and behaviour, and human factor needs). Outputs from this work will feed into the user requirements and Re-cognition system evaluation.

3) Co-develop a public engagement project with the public group that explores their relationships and views of the Re-cognition project and the impact it might have on their future. The output will be disseminated with other pilots and the wider public.

The UoB will use this process to help inform the creation of activities, resources and support that will enable other partners to employ a similar pilot-public engagement approach with their pilots. The UoB will be providing on-going support to all partners through this public engagement process. Overall this public engagement process will enable partners to practise inclusion of diverse range of voices; promoting them to work with publics to collectively anticipate and reflect upon Re-cognition technology and the potential impact and implications it may have in future societies.

## Progress and reflections so far

Since the start of the Re-cognition project, an initial RRI workshop has been held with consortium members, alongside on-going discussions and development meetings with RRI experts at the University of Bristol. The outcome of both of these activities has led to the identification or key stakeholders and also the identification of RRI Re-cognition themes that will be used to focus all stakeholder-related engagement activities throughout the project.

## Key Stakeholder Identification

This section will focus on identifying the key stakeholders that should be involved within the Re-cognition project. Stakeholders play a key role within the project; therefore, it is crucial that comprehensive methods are undertaken to not only identify appropriate stakeholders but to also broaden and diversify the stakeholder group to amplify the voices that are able to influence the project.

### Preliminary Stakeholder Group

Firstly, various stakeholder groups were mentioned in the Re-cognition bid document. The groups mentioned in this document have been used to create the preliminary stakeholder group. Table 1 details the groups identified.

Table 1 List of stakeholders mentioned in the DOA

| Renewable Energy Sources-related industry sector | End users | Facilitators |
|---|---|---|
| ➢ Leading industries (such as CHP producers, Solar Thermal and Solar Cooling apparatus, PV panels producers, biogas producers, etc.)<br>➢ System integrators<br>➢ RES applications designers & developers<br>➢ Private energy providers<br>➢ Infrastructure operators<br>➢ ESCO<br>➢ Aggregators<br>➢ Other relevant investors | ➢ Local energy consumers (spanning from the individual citizen to small and medium production facilities and commercial and public buildings).<br>➢ Technology and service providers in the areas of RES installation and maintenance.<br>➢ Building and facility Manager<br>➢ Local Energy Manager<br>➢ Equipment Installers<br>➢ End-Prosumers | ➢ EU initiatives such as the European Committee of Electrical Installation Equipment Manufacturers – CECAPI, ASSISTAL, Italian National Association of Plant Builders, European Construction Industry Federation – FIEC, Federation of European Heating, Ventilation and Air Conditioning Associations – REHVA, Renewable Energy Cooperative – RESCOOP.eu<br>➢ Standardisation Bodies<br>➢ Institutions<br>➢ NGOs<br>➢ Research community with a special focus on RES and their integration at equipment and building level and<br>➢ Legislators and policymaker including relevant ministries<br>➢ Energy and environment NGO association and platforms such as DHC+, RHC+ etc.<br>➢ European Association for Storage of ENERGY (EASE)<br>➢ European Energy Research Alliance (EERA), E2B Association, ARTEMIS Industrial<br>➢ Association OPEARD Alliance<br>➢ EPoSS European Technology Platform on Smart Systems Integration<br>➢ Smart Energy Demand Coalition<br>➢ International organizations such as ICLEI, Energy Cities, Covenant of Mayors, etc. |

This preliminary stakeholder group (Table 1) was discussed and expanded upon during the RRI training that took place at the University of Bristol from the 3rd to 4th of July forming a newly defined external stakeholder group. The newly identified external stakeholder group will act as the foundations for the stakeholder engagement activities, but the group is expected to evolve throughout the project.

#### Responsible Research and Innovation Training in Bristol

The Re-cognition RRI training took place at the University of Bristol from the 3rd to 4th of July 2019. The main aim of this training session was to introduce the team to the concept of RRI and what role it will play in the Re-Cognition project. Overall, 14 participants attended the session from 10 of the Re-cognition consortium member organizations. Over the two days participants took part in a series of talks and participatory activities that required them to engage with RRI, understand its application to engineering and then begin to explore the relevance of RRI within Re-cognition. These activities were designed to enable participants to have conversations around who might benefit from this technology in the future? Who might be negatively impacted by this technology? Who should be consulted about this technology during the development? Therefore, conversations from these sessions gave rise to a broader and more diverse range of stakeholders.

Efforts will be made in creating a balanced group of building eco-systems' stakeholders and end-users based on age, gender, socio-cultural backgrounds and technology literacy. This list is by no means exhaustive and is expected to evolve throughout the project developments.

Table 2 External Stakeholder group identified through the RRI training

| Renewable Energy Sources-related industry sector | End users | Facilitators | Other Groups |
|---|---|---|---|
| ➢ Leading industries (such as CHP producers, Solar Thermal and Solar Cooling apparatus, PV panels producers, biogas producers, etc.)<br>➢ System integrators<br>➢ RES applications designers & developers<br>➢ Private energy providers<br>➢ Infrastructure operators<br>➢ ESCO<br>➢ Aggregators<br>➢ Other relevant investors<br>➢ National Grid<br>➢ Other companies working on similar RES technology | ➢ Local energy consumers (spanning from the individual citizen to small and medium production facilities and commercial and public buildings).<br>➢ Technology and service providers in the areas of RES installation and maintenance.<br>➢ Building and facility Manager/Owners<br>➢ Local Energy Manager<br>➢ Equipment Installers<br>➢ End-Prosumers<br>➢ Wider public (a diverse group of people, from different backgrounds that is representative of the population)<br>➢ Equipment maintainers<br>➢ Disabled workers | ➢ EU initiatives such as the European Committee of Electrical Installation Equipment Manufacturers – CECAPI, ASSISTAL, Italian National Association of Plant Builders, European Construction Industry Federation – FIEC, Federation of European Heating, Ventilation and Air Conditioning Associations – REHVA, Renewable Energy Cooperative – RESCOOP.eu<br>➢ Standardisation Bodies<br>➢ Institutions<br>➢ NGOs<br>➢ Research community with a special focus on RES and their integration at equipment and building level and RRI Scholars<br>➢ Legislators and policymaker including relevant ministries<br>➢ Energy and environment NGO association and platforms such as DHC+, RHC+ etc.<br>➢ European Association for Storage of ENERGY (EASE)<br>➢ European Energy Research Alliance (EERA), E2B Association, ARTEMIS Industrial<br>➢ Association OPEARD Alliance<br>➢ EPoSS European Technology Platform on Smart Systems Integration<br>➢ Smart Energy Demand Coalition<br>➢ International organizations such as ICLEI, Energy Cities, Covenant of Mayors, etc. | ➢ Followers on Social Media<br>➢ People from countries not represented within the Re-cognition consortium countries<br>➢ Nearby Communities and Neighbourhoods<br>➢ City Councils<br>➢ Building occupants/workers<br>➢ Utility companies<br>➢ Schools |

## Key Re-cognition RRI Themes

Key RRI themes for the project emerged out of the first RRI workshop and from topics described in the T1.2 deliverable tasks (i.e. socio-technical issues, impacts on human sensory and behavior, and human factor needs). These themes were identified as requiring further attention and discussion. It is worth noting that the themes listed below are likely to evolve and be influenced by project developments as it progresses.

1. **Risk and mitigation, optimising benefits**

This theme comprises considerations of (a) responsibility towards end-users, optimising benefits and minimising risk, ensuring human comfort and safety; (b) how to mitigate and minimise harm in the production and after-life of technologies; (c) effective stakeholder and public engagement to meet (a) and (b).

2. **Digital security and user data**

This theme encourages partners to reflect on the potential risks associated with digital security and user data and consider how to mitigate those risks.

3. **Future thinking**

This theme encourages partners to consider potential future applications and implications of the project's technology, reflecting on the potential impacts for people and the planet.

4. **Public engagement**

Interlaced with the above themes, partners will be continuously encouraged to reflect on which groups the project should engage with in order to invite more voices into the conversation and create a reflexive and responsive process of research and innovation.

# 5 Impact and Standards: A Literature review

Re-Cognition project will implement a number of different technologies configurations that include renewable energy sources, storage systems, charger systems and software (see Figure 2). The following section describes the impact of the technologies proposed by the project on human health and environments and a detailed literature review of regulation and standards that govern their implementation within the EU.

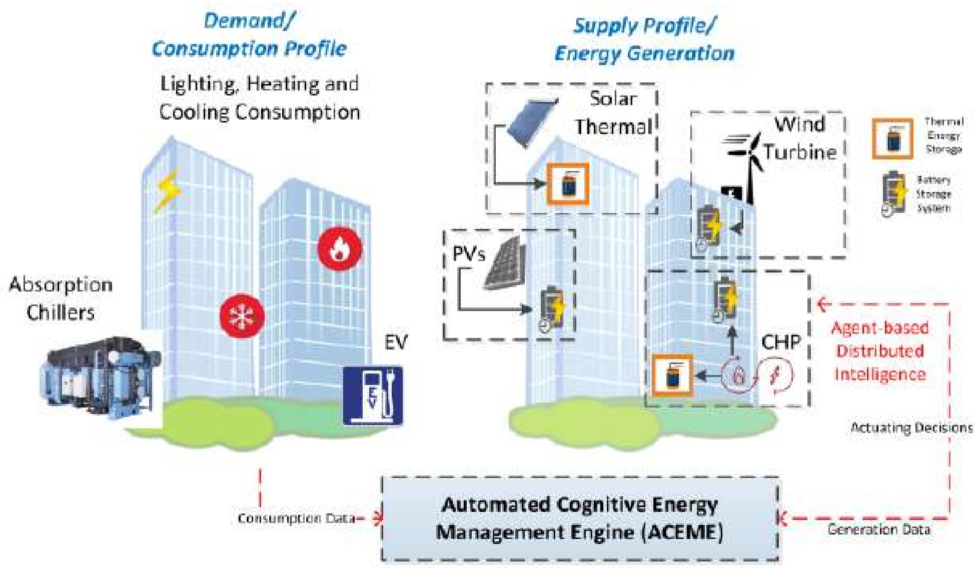


Figure 2 Technologies tested/deployed in Re-Cognition

## Impact of electromechanical RES equipment and Human factors

In this section it is reported the state of the art regarding the impact of electromechanical RES equipment on the human factors and the associated tolerance levels depending on the application environment (office, residence, industry).

## Thermal Energy Storage

Most of the energy for heating and cooling in the EU comes from fossil fuels (82%). Nevertheless, the EU has set ambitious energy targets that aim to reduce greenhouse gas emissions by 40% and an increase of the share of renewables to at least 27% within 2030 [3]. Relying on fossil fuels implies the total availability of satisfying the heating demand whenever requested by end-users, mostly thanks to the vast extension of the European natural gas grid. On the other hand, renewable energy sources are characterized by different degrees of intermittency, thus they are less reliable.

In this context, the path towards the decarbonization of the heating sector needs a pivotal additional element: thermal energy storage technologies. Typically, thermal energy storage (TES) systems are classified in three categories: 1) *sensible heat storage*, that exploits the temperature increase or decrease of a liquid or solid storage medium (e.g. water, sand, molten salts, rocks); 2) *latent heat storage*, which exploits the phase change process of specific materials, indeed know as phase change materials (PCMs); 3*) thermo-chemical storage* (TCS) based on the thermal energy balance of chemical reactions [4]. If properly managed, they can enable flexibility and energy security, which renewable sources alone cannot guarantee. Indeed, they can support the balancing of energy demand and supply on a daily or weekly basis and they can also help reducing peak demand and energy consumption [4].Therefore, the impact of storage technologies on human life and organization is expected to be relevant as they are intended to replace part of the current system for heat supply to end-users.

Unfortunately, despite the energy advantages previously mentioned, PCM storage systems (like the one developed within RE-COGNITION framework) might appear as non-inclusive technologies from a social perspective due to their current elevated cost. The price of the raw phase change material alone ranges from 50 to 7000 €/m$^3$ [5]. Moreover, thermal storage units cannot satisfy the heat demand requested by end-users on their own, but they need to be coupled to heat generating technologies (such as solar collectors or heat pumps) thus further increasing the investment costs for the whole system. On the other hand, the majority of sensible storage units is cheaper thanks to the negligible cost of water [5]. However, they require larger volumes, up to three to five times larger than PCM for the same energy output. Consequently, fewer people can afford either the cost or the space for their installation. Therefore, without favourable policies or economic conditions, social differences might be sharpened. On the contrary, ad hoc incentives would increase the number of people able to sustain this investment. Nevertheless, the autarky (here intended as the independence of supply for the consumer) attained through energy storage systems may result a crucial factor for their adoption. Indeed, a study reveals that homeowners' willingness to pay extra for energy storage technologies is increased when autarky benefits are emphasized [6]. In fact, psychological motives such as self-sufficiency and supply security reinforce this predisposition. Furthermore, at the community scale (such as a condominium) energy storage projects have "*the ability to engage the community in energy issues, improve receptivity to renewable energy and engender behaviour change*" as reported in [7]. As a demonstration, community awareness on energy-related topics increased from 35% to 42% after a two-year project in UK [7]. Nonetheless, the nature of storage technologies itself may hinder their diffusion. End-users may perceive their adoption with little enthusiasm due to the additional role that storage units play within heating systems. As already mentioned, they do not constitute an essential element for the production of heat, but they assist generating technologies. Consequently, end-users may not be fully aware of their potential.

A further aspect to consider when analysing the impact of thermal energy storage on our society is the way people usually interact with their heating system and consumers' habits. Generally, this interaction is driven by different factors, such as energy cost, technology awareness, environmental sensibility and level of education. For instance, a sample study in UK [8] identified different approaches to hot water heating, characterised by the choice of different heating technologies. A first group mostly valued the household well-being aiming at a full availability of hot water for all needs. On the other hand, a second group used to employ a lower amount of hot water by matching daily routines with pre-programmed system activation or by relying only on solar collectors' production for personal financial benefit or environmental sensibility. In this context, a larger deployment of efficient thermal storage systems in combination with RETs may have positive effects both for human habits and for the environment. Indeed, people willing to install renewable energy technologies for their own heat supply can avoid paying the price of an inflexible system, while those with an indifferent attitude can still satisfy their needs without detrimental effects on the environment. Simultaneously, they may increase their awareness on the interrelation among human habits, energy and environment, thus fostering the achievement of European targets.

Regarding the implications on human health, thermal energy storage technologies don't require particular precautions. Usually, they are not coupled to electromechanical equipment and the operating temperatures in the building sector are well below 100°C. However, a general issue that should be cared for in sensible heat storage units, like hot water tanks, is the presence of legionella bacteria. If this bacterium is not properly contrasted, it may cause even death when inhaled. Nevertheless, increasing the temperature in the tank above 60°C once a day is sufficient to eliminate the risk of proliferation of these bacteria. A further issue concerns latent heat thermal energy storage technology based on phase change materials (PCMs). They may be toxic or flammable when the substance is not properly confined inside the container. PCMs can be classified in three main categories: organic, inorganic and eutectic. Organic PCMs are flammable in nature and some of them, like paraffin waxes, contain volatile compounds whose vapours are cancerogenic in case of long exposures. However, on the market there are also non-toxic organic PCMs, like vegetable oils, which are generally considered safe when proper fire safety precautions are followed. Inorganic PCMs are metals or salt hydrates. They are considered safe, they are not flammable, but depending on the substance they can be toxic and cause skin or eye irritation and respiratory problems when not carefully handled. Finally, eutectics are mixtures of two (or more) compounds which show congruent melting or freezing. Their toxicity is strictly dependent on their constituent materials (organic or inorganic) [9].

A further aspect that should be taken into account is the implication of thermal energy storage technologies on the environment. Sensible heat storage units are not complex devices and their manufacturing, operation and disposal phases don't cause a relevant concern for the environment. Instead, latent heat storage units based on PCMs should be regarded with more care because of the risk of flammability that some compounds possess. Furthermore, substances like paraffin add a considerable environmental load during manufacturing and are also non-renewable and non-biodegradable, thus their disposal constitutes an issue [9].

However, the material chosen for the PCM thermal storage in RE-COGNITION project will consider all the concerns expressed above and select a reasonable solution among numerous opportunities.

## Building Integrated Photovoltaic (BIPV)

According to the European legislative framework, the Building Integrated Photovoltaic (BIPV) impact on human activity and environment must be controlled and contained with particular regards to toxic gases, emission of dangerous substances or their release in environment and in drinking water. In this regard, the European CPR 305/2011 [10] states: "The construction works must be designed and built in such a way that they will, throughout their life cycle, not be a threat to the hygiene or health and safety of workers, occupants or neighbours, nor have an exceedingly high impact, over their entire life cycle, on the environmental quality or on the climate during their construction, use and demolition."

BIPV system sustainability throughout its complete life cycle should be guaranteed by owner or user "from raw material acquisition or generation from natural resources to final disposal" avoiding the use of toxic materials or significant amounts of rare materials, as well as designing products which could be readily separated into their components to facilitate the recycling [11].

The risk related to module's fire is predominant and it is mainly associated to the impact of chemical release on human health [12]. Lead (Pb) is present in very small quantity in Crystalline-Silicon (c-Si) modules, even if many manufacturers are switching to lead-free PV panels. However even in worst-case fire scenarios the impact on health is not significant [13]. Cadmium (Cd) and Selenium (Se) are present in thin film technologies, however their market share is lower than 5% [14]. Screening-level human health risk assessment methods have been performed by different institutions, as the International Electrotechnical Commission [15] and Bavarian Environmental Protection Agency [16], using VDI Guideline 3783 Sheet I [17]. Considering inhalation exposures over an interval of 10 minutes to 8 hours, the potential incremental cancer risks associated with inhalation of Pb and Cd from Photovoltaic (PV) modules are lower than the 1×10-6 (one in a million), which is considered negligible by regulatory agencies like USEPA [12]. Risks for the environment come from the extinguishing of fire with water, that may result in transport of particulates to soil and/or groundwater [18]. Simulation of soil and groundwater contamination levels during buildings' fire have been calculated and compared with the maximum contaminant levels (MCLs) set for public water systems. According to the simulation, the amount of concentrations of Pb, Cd, and Se in groundwater from PV modules are below the groundwater MCL [12].

Another problem is related to potential disturbing reflections occurring when sunlight strikes BIPV installed in façades, as happens with all glazed or reflective building surfaces. It can cause glare and heating of the surroundings, which should be considered and avoided during design phase, even if such problems often occur only when construction is completed. Thus, from the early design stages it is necessary to consider the building morphology, the surrounding environment and the materials used, as PV glass optical properties [11].

Radiation intensity and reflection angles are the most important factors in dazzling [19]. Glass reflectance, for example, is quite low for normal solar incident radiation, but increases significantly for angles of incidence above 60° [11]. The dazzling on the ground occurs in the presence of high sun and vertical, or very inclined, surfaces, meaning that in the northern hemisphere the main problems occur when the facades surface azimuth varies between +45° and -45° to south axis and with slope included between 5° and 30° to the vertical, while is not significant for larger slopes [19]. However, for such reasons, different studies stressed the attention on rooftop- more than façade-BIPV on residential and industrial buildings because of the lower visual and glare risk [20].

## Hybrid Solar Cooling

Air conditioning and cooling (ACC) accounts for 20% of the overall electricity consumption worldwide [21] and is forecasted to increase [22]. The majority of the human population live in warm and humid climates thus give a huge importance on latent heat load where desiccant solid and liquid materials can play a key role in lowering the pression on the electrical grid. Different papers in literature [23]–[27] highlight better performances of this kind of system with respect to traditional vapor compression cycles in terms of energy consumption and efficiency. Moreover, the new EU targets set to 32% the RES share in gross final energy consumption by 2030 [22][28] and, in order to satisfy this ambitious goal, the heating and cooling sector needs to shift towards renewable sources since it still relies massively on fossil flues, especially the heating part [29]. The cooling needs has been mainly tackled since now with electrically driven technology, we have learnt to deal with huge peak power loads during summer hot period which overload the electrical grid. Moreover, ACC units and heating devices play a major role in the emission of gases which causes depletion of ozone and other environmental issues [30]. Nevertheless, thermally driven technologies have been studied and they have the potential to shift part of the cooling load towards thermal energy that can be produced from RES such as solar thermal module or waste thermal energy, decreasing the emissions of the aforementioned gases. Among the different thermally driven technologies, the solar dehumidification processes are considered among the most effective and more convenient. At the end of 2015, an estimated 1350 solar thermal cooling unit had been installed worldwide; around 80% of them in Europe [21].

The Hybrid solar cooling (HSC) systems that will be developed will tie together the advantage of desiccant materials, to lower the latent load for vapor compression cycles, and will use clean thermal energy produced by the solar collectors to regenerate the desiccant material. This will have a positive impact on environment and climate issues due to the lower energy required and will contribute to reducing the demand on the electrical grid. The electricity needs for this technology will be lower for the same cooling power of a traditional air conditioning unit. Thus, it can be covered by the solar PV modules and the regeneration of the desiccant material will be done using solar thermal energy and/or with rejection heat, increasing the RES utilization, even locally produced, and lowering the electricity demand from the grid. Moreover, due to the desiccant contribution in handling the latent heat load, smaller amounts of refrigerant gas will be needed, following the EU directives on refrigerants [31], [32]. Less refrigerants means also decreasing the flammability and toxicity risks as well as the leakage of harmful gases.

Since this kind of technology is relatively new and not widely used there are no effective and detailed clue about its social implications. Nevertheless, as written in the first part of this paragraph, cooling devices are increasing their presence in our working place and houses. Larger share of the world population is improving their quality of life. The HSC system has a good potentiality to increase the user's awareness around RES and energy efficiency since it provides the same service of an air conditioning unit, using larger share of renewable energy and lowering the energy request from the grid.
The health implications of this technology are significant with regards to its implications which are playing, and will play, an important role in the air treatment field. Air pollution is considered as the world's largest environmental health threat [33], [34]. People are spending more and more time in closed environments and heating/cooling air devices have to create a comfortable environment in order to improve well-being and productivity of users, with a particular attention to health and air quality. In fact, such systems can be equipped with air filters and devices [35] in order to trap pollutants and guarantee a safe internal environment for users. Desiccant materials, that we are going to use (Silica Gel and Zeolite) do not pose major hazards for health. Looking at the *European Chemicals Agency* [36] we can see that there are some hazards [37], [38] like skin/eye irritation, but they are more related to the production phase of these materials more than their final use; this is also stated in material data sheets from different producers [39]–[44].

Regarding the end of life of the systems, the main components, such as heat exchangers and valves, are made from different types of metals (aluminium, copper, iron etc.) which are recyclables through fusion and re-forging procedures. Silica gel and Zeolite, the two major candidate as desiccant materials, can be re-used for different applications if they did not come into contact with toxic substances. Then, they can be simply moved into the general waste if, again, no toxic contamination occurred. At last, refrigerants must be handled carefully during all the different phases: first load, operation, re-load and final discharge of the system. Certificates industries and personnel have to be called for maintenance and disposal in order to avoid environmental and health hazards [32], [45].

## Wind Turbines

The RES technology for wind turbines in the project is a small vertical axis wind turbine driven by passive variable geometry, coupled to permanent magnet generator, and integrated in power electronics system and in building, with a preference for rooftop installation for enhanced building scale integration. Small Wind Turbine (SWT) are subject to regulatory framework set by local and national authorities. These are country dependent or even region/province dependent. The SWT in Re-Cognition consists in a “micro” wind turbine with geometrical dimensions (1,5 x 1,5 m) sufficiently small to accomplish with the great majority of regional authorization rules: e.g. at the project Proposal stage it has been checked that local Corby, UK provisions for SWT are satisfied and similar to the Italian Architectural Heritage Preservation code. SWT are also subject to regulatory framework at the building level e.g. family, legal person or condominium communities to **manage the energy production, distribution and use**. This is particularly relevant for the system integration of the RES included in the project.

With regards the Human Factor and the potential risks for human health, we can distinguish between consideration about the safety and comfort. In particular, these are linked to the human exposure to vibration and human exposure to electromagnetic fields. Human exposure to vibration is related to SWT machinery motion in the case of occupancy near the rooftop installation and is precisely of the **whole-body vibration** type as regulated by ISO 2631: 1997 updated 2014. The range of vibration conveyed by the SWT is within the 0-15 Hz range (n° of blades * max RPM / 60 = 3 * 325 / 60), that is low-frequency vibrations (< 80 Hz). Generally speaking, stressed by low-frequency vibrations, the human body responds uniformly, that is, as a single and homogeneous mass, thanks to the musculature's ability to stiffen and counteract stresses. If the external forcing action has one frequency that coincides with the frequency natural of the solicited system (human body), one can obtain the resonance conditions, which can cause an exaltation of the amplitude of vibratory motion (example: the swing). Whole body vibrations still present aspects not clarified. Studies show that the role of vibrations in the aetiology of changes in the lumbar spine is not yet completely highlighted [46] Driving cars or vehicles do not only expose humans to harmful vibrations, but also to ergonomic stress factors (prolonged seated posture or frequent bending movements and twisting of the spine). Biodynamic studies have shown [47], among others the possible mechanisms of injury to the spine, due to mechanical overload to phenomena of resonance of the vertebral column in the frequency range of vibrations between 3 and 15 Hz (truck seats, vans, etc.). The consequences are structural damage to the vertebral bodies, discs and intervertebral joints.

There is sufficient epidemiological evidence of the risk of occurrence of pathologies of the lumbar spine being proportional to the duration and intensity of the exposure. In order to reduce risk from vibrations, the parameter of greatest interest is the acceleration transmitted by the machines to the organs of the human body. The acceleration is more significant than other physical quantities (e.g. speed) because it is representative of the variations of the stimuli generated by the vibrations and felt by humans (energies and forces). In the field of industrial hygiene, the effective value of the acceleration is used, expressed in $m/s^2$ (or in multiples of g, gravity acceleration) I.e. the square root of the mean of the squares in a certain time interval T of the instant values of the acceleration.

The measurement of such acceleration is then weighted in frequency as there are different sensitivities of the human body to the various frequencies. Frequency weighting is generally carried out by signal filters providing attenuation at some frequencies and amplification for others.

The final evaluation is then performed with different methods according to the resulting peak factor, as highlighted in the following chart from ISO 2631.

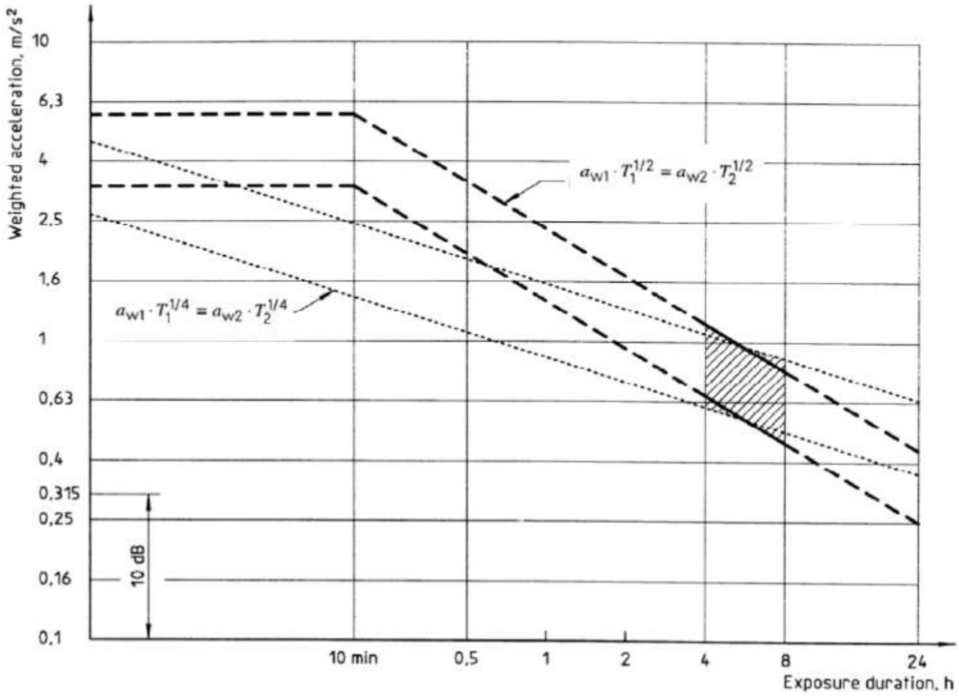


Figure 3 Evaluation methods Maximum Transient Vibration Value (upper curve) and Vibration Dose Value (lower curve) to be used for crest factors above a critical value (>9). Source: [ISO 2631]

The SWT RES will be designed in order to deliver acceleration levels that are compliant with the limits provided by the relevant methods, according to the Responsible Research & Innovation pillars of our project's pledge.

Human exposure to vibration is also connected to **noise exposure**. A sound source that could be generated by the SWT is characterized by the sound power, measured in watts. The effect of an acoustic source on the listener is evaluated with the acoustic pressure, measured in pascals. The sound decibel (dB), which is the unit for measuring the sound pressure level (Lp) is given by the following formula:

dB = 10 log ($P^2$ / $P_0^2$) where $P_0$ is the minimum perceivable sound pressure by human ear, and P is the source

Being 140 dB the pain tolerance level, workers safety regulations according to EU Directives 2002/44 and 2003/10 state that 80 dB(A) [1] is the lower limit of noise for which no medical assistance is required, and accordingly 50-60 dB(A) is the limit recommended for mixed use urban areas (night-daytime).

[1] The difference between dB and dB(A) units, is a weighting procedure according to the human audibility curve A correction

For SWT, some acceptability criteria are not found in IEC 61400-11 as are found e.g. in the AWEA (American Wind Energy Association) Rated Sound Level for SWT. The AWEA Standard 9.1 specific for "Small Wind Turbine Performance and Safety Standard", indicates different "AWEA Rated Sound Levels" as acceptability criteria for turbine noise, starting from the minimum 40 dBA class, up to the 55 dBA class. This means that the sound level calculated e.g. at a distance of 20 m from the rotor hub, depending on each class of background noise level (30 to 50 dBA accounted), should be less or equal than 49.6 dBA in the 30 dBA background noise class.

Table 3 Overall Sound Levels at Different Locations for an AWEA rated sound level of 40 dBA

| Distance from rotor center [m] | $L_{AWEA}$: 40 dBA | | | | |
|---|---|---|---|---|---|
| | background noise level (dBA): | | | | |
| | 30 | 35 | 40 | 45 | 50 |
| 10 | 55.6 | 55.6 | 55.7 | 55.9 | 56.6 |
| 20 | 49.6 | 49.7 | 50.0 | 50.9 | 52.8 |
| 30 | 46.1 | 46.4 | 47.0 | 48.6 | 51.5 |
| 40 | 43.7 | 44.1 | 45.1 | 47.3 | 50.9 |
| 50 | 41.9 | 42.4 | 43.9 | 46.6 | 50.6 |
| 60 | 40.4 | 41.2 | 43.0 | 46.2 | 50.4 |
| 70 | 39.2 | 40.2 | 42.4 | 45.9 | 50.3 |
| 80 | 38.2 | 39.4 | 41.9 | 45.7 | 50.2 |
| 100 | 36.6 | 38.3 | 41.3 | 45.5 | 50.2 |
| 150 | 34.1 | 36.8 | 40.6 | 45.2 | 50.1 |
| 200 | 32.8 | 36.1 | 40.4 | 45.1 | 50.0 |

Such classification is highlighted in AWEA 9.1 Tables of Annex A: the relative Table1 for the minimum 40 dBA AWEA Rated Sound Level, is proposed below:

According to [IEC 61400-11][2], and [AWEA 9.1][3] Annex A, it is recommended to take into account a correction for background noise when evaluating acoustic noise from a wind turbine. Therefore, the same method will be used for the proposed SWT.

During the project, a vibration insulation device specific for Windcity's SWT is being developed from elastomeric components, in order to de-couple the motion of the SWT and its rigid support from the motion of the hosting structure. While avoiding resonance conditions, such de-coupling will also be the measure to minimize the vibration transmitted to the hosting structure having human occupancy, and therefore the noise associated to vibration, according to the Responsible Research & Innovation pillars of our project's pledge.

Concerning electromagnetic fields EMF, since the frequency associated to a 11-poles SWT permanent magnet generator is RPM * poles / 60, and that associated to a common inverter is 50-60 Hz, one has to evaluate **human exposure to extremely low frequency EMF**, i.e. in the range from 3 to 300 Hz.

[2] IEC 61400-11:2012/AMD1:2018 Wind turbines - Part 11: Acoustic noise measurement techniques and IEC 61400-2:2013 Wind turbines - Part 2: Small wind turbines

[3] American Wind Energy Association, AWEA Small Wind Turbine Performance and Safety Standard. AWEA 9.1-2009, Washington, DC: AWEA; 2009

According to the International Commission on Non-Ionizing Radiation Protection ICNIRP, guidelines for maximum general public exposure range from 200 microTesla for 40 Hz to 100 microTesla for 800 Hz[4].

However, according to the World Health Organization, International Agency for Research on Cancer Press Release n° 136/2001, correlated to IARC Monographs 80 & 102[5], pooled analyses of data from a number of well-conducted studies show a fairly consistent statistical association between a doubling risk of childhood leukaemia and power-frequency (50 or 60 Hz) residential ELF magnetic field strengths above 0.4 microTesla.

In its questionable conclusions, the [ICNIRP] guidelines state that, as a "causal relationship between magnetic fields and childhood leukaemia has not been established" by the IARC findings, "this effect cannot be addressed in the basic restrictions". The issue is today particularly debated regarding hybrid and electric vehicles [48].

Nonetheless, according to the Responsible Research & Innovation pillars of our project's Oath, during the project a permanent magnet generator and an inverter are used for Windcity's SWT, and their EMF emissions in a low-range from 20 to 100 cm range are monitored to be not higher than 0.2 microTesla, i.e. according to the WHO (IARC) evidences suggesting a maximum exposure up to 1000 times lower than ICNIRP.

Implication for animals are associated with **possible interference with flying birds and their habits** in general. Given the overall dimensions of the SWT are 1.5x1.5 m to be positioned on rooftops, the type of interference shall be limited to that of a common TV antenna, i.e. of an object already included in the urban environment perceived by birds, thus not interfering with their flight or migration paths as possibly happening for high rating wind turbines (> 100 kW).

Due to the fact that the SWT is a rotating and not static object, it could cause interference with birds' take-off & landing habits, should the birds not perceive the SWT as a moving object. Usually, problems of birds not perceiving an obstacle are mainly associated with transparent surfaces (roadway barriers, glass façades etc) and not with translucent objects such as the SWT in this project.

There is experimental evidence in literature [49] shows that bird activity is similar near and away from SWTs and is not affected by SWT operation at the fine scale studied. The same study suggests planning SWT installations at least 20 m away from potentially valuable bat habitat.

Nonetheless, according to the Responsible Research & Innovation pillars of our project's pledge, we shall adopt signalling 'birds stickers', usually applied to avoid crashes of birds into transparent surfaces.

Implication for the environment is mainly associated with the **Energy Return on Energy Invested EROEI ratio** of the SWT, which is one of the key performance indicators adopted in the project. Thanks to the extensive use of aluminium alloys material, Windcity's RES provides a fully recycled and recyclable device (see also D1.3).

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[4] For more info see the website: https://www.icnirp.org/

[5] World Health Organization WHO - International Agency for Research on Cancer IARC, Static and extremely low frequency electric and magnetic fields. Lyon, France: IARC; IARC Monographs on the Evaluation of Carcinogenic Risk to Humans Volume 80; 2002

## Energy Storage Systems

Energy storage technology enables building managers to maximise the benefits of intermittent RES generation. Unused electrical energy produced during periods of high generation can be stored for later use when building usage exceeds RES production (e.g. excess electrical energy from solar PV can be stored during the day and used to meet evening demand). Maximising the use of RES and reducing the amount of electricity purchased from the grid will save small and medium sized building owners money and help reduce emissions.

The most common renewable energy storage device used by small and medium sized buildings are batteries. Other energy storage systems exist (e.g. flywheels, liquid air and compressed air) but are not in widespread use at the time of this report. Battery storage offers a highly efficient and practical solution for converting energy into a form where it can be stored safely, in a relatively small space (an important factor for small and medium sized buildings) and then made available for instant use on demand [50].

A typical battery storage system consists of an energy storage medium based on battery cells, a management system and an inverter. There are many commercially available battery systems and a range of battery chemistries. Two of the most common chemistries are lead acid and lithium ion batteries [51].

- Lead acid batteries are an established technology used in many applications including conventional car starter batteries. Although they are relatively cheap, they suffer from a relatively short life, are quite heavy and have a lower depth of discharge (DoD) than some other battery types (i.e. typically recommended to use only up to 80% of lead acid battery capacity before recharging).
- Lithium ion batteries come in several types (chemistry and structure) and are common in home and small/medium building battery technologies. They are generally smaller, lighter, longer lasting and allow a greater DoD than their lead acid equivalents (typically up to 95% of battery capacity before recharging is recommended).

The choice of battery will depend on many factors, such as the desired power rating (kW), effective capacity (kWh), required life expectancy, charge/ discharge efficiency, physical size (energy density) and siting requirements. Considerations include ventilation, operating temperature range, discharge power, charging power, available physical space, and suitability for outdoor use.

The most common stationary battery for small and medium sized buildings is the lithium-ion battery because of their high energy and power output and high efficiency [52]. Furthermore, the high costs that have hitherto prevented wide-scale uptake have reduced significantly over the last few years[6].

There are a number of lithium-ion battery technologies under development and the chemistry of these influences their potential environmental and safety impacts. The major chemistries in production are based on a graphite anode paired with different cathode materials. These include lithium nickel manganese cobalt oxide (NMC), lithium iron phosphate (LFP), lithium nickel cobalt aluminium oxide (NCA) and lithium cobalt oxide (LCO). To date NMC and LFP chemistries have the largest market share for use in stationary energy storage and electric vehicles[7].

[6] https://www.bloomberg.com/news/articles/2019-04-03/battery-reality-there-s-nothing-better-than-lithium-ion-coming-soon - accessed September 2019

[7] https://www.gminsights.com/industry-analysis/lithium-ion-battery-market - accessed September 2019

In the coming years these two battery chemistries are expected to have a high rate of market uptake, however, they have a range of social, human rights, health and safety and environmental impacts.

### Social impacts

The impact of energy storage technologies can be associated to human rights issues associated to the extraction of the minerals needed for their fabrication. Moreover, the technology presents a number of health and safety risks.

### Human rights

Human rights impacts are associated with the mining and processing of materials for lithium-ion batteries. The extraction of cobalt and lithium present the two major issues.

### Cobalt extraction

The Democratic Republic of Congo (DRC) is the world's largest producer of cobalt, accounting for over 60% of global production[8].

Significant human rights issues are associated with the mining of cobalt in the DRC. These include unsafe conditions of 'artisanal' and small-scale miners, poor working conditions in industrial mining companies, and extensive child labour. Around 20% of the cobalt exported from the DRC is mined informally by locals, known as 'artisanal' miners. There are an estimated 255,000 artisanal cobalt miners in DRC (at least 35,000 are children) who mine by hand-digging tunnels deep underground without proper tools or safety equipment [9].

The miners face a constant risk of tunnel collapse, particularly during the rainy season and death by suffocation or drowning.

Large mining companies have excluded artisanal minors from large areas of land that they previously had access to restricting them to a small number of zones in areas unsuitable for industrial mining[10].

There are reports that artisanal minors are forced to pay bribes to local government officials to gain access to mines in illegal areas or ensure they turn a blind eye to child labour[11].

Child labour is widespread. Children are used to gather rocks containing cobalt from discarded industrial spoil or sort and wash ores. In addition, they are at risk of physical abuse and financial exploitation from security guards employed by mining companies. The children lacked knowledge of commodity prices were susceptible to exploitation from traders[12].

Many of the mining companies in the DRC are Chinese owned. There are of estimated to be around 60 Chinese-owned companies, including smelters and trading houses. Workers in Chinese mining companies operating in the DRC have reported a lack of adequate protective clothing, training and safety procedures. Following accidents workers are denied adequate medical treatment or compensation and beatings by security guards are commonplace. Children have been reported to work in Chinese trading houses and the minerals traded are often from artisanal mines that may include child labour. Many of the workers lack job security and do not receive the same benefits, such

[8] https://www.theguardian.com/global-development/2018/oct/12/phone-misery-children-congo-cobalt-mines-drc - accessed September 2019

[9] https://www.theguardian.com/global-development/2018/oct/12/phone-misery-children-congo-cobalt-mines-drc - accessed September 2019

[10] https://www.frontiersin.org/articles/10.3389/fenrg.2018.00123/full - accessed September 2019

[11] https://www.amnestyusa.org/files/this_what_we_die_for_-_report.pdf - September 2019

[12] https://www.amnestyusa.org/files/this_what_we_die_for_-_report.pdf - September 2019

as medical care, set working hours and overtime as those employed by the state-owned mining company Gécamines[13].

### Lithium extraction

The 'lithium triangle' denotes a region of South America covering parts of Argentina, Chile and Bolivia. It has been estimated that South America's Lithium Triangle hosts around 54% of the world's lithium resources [14].

A significant issue in this region is that the extract of lithium uses a lot of water (approximately 500,000 gallons per tonne of lithium). The 'lithium triangle' is one of the driest places on earth and in Chile's Salar de Atacama, mining activities have reportedly consumed 65% of the region's water which has a big impact on local farmers [15].

In Chile and Argentina, lithium mining occurs on the land of the indigenous Atacama people. The mining has created divisions in indigenous communities. Some community members oppose mining in the salt flats as they are considered sacred whereas others are grateful for the new job opportunities.

In Chile, the Atacama people remain in poverty, despite decades of lithium mining. Lithium mining began in the Salar de Atacama in the 1980s and only in 2016 has the mining company agreed to make payments to indigenous communities at an expected 3% of annual sales[16].

In Argentina, a mining operation in the Cauchari Olaroz Salars has struck deals with local communities for extensive surface and water rights. The operation is expected to generate around $250 million a year in sales while each community will receive annual payments of between $9000 to $60000 per year[17].

Perhaps the greatest concern to communities is that lithium mining could contaminate water sources and divert water away from local communities, worsening existing water shortages[18].

The area has experienced drought for several years and water is critical for communities, including for agriculture and grazing.

### Health and safety

Li-ion batteries are classified as 'dangerous goods' and present safety risks during transport, installation, use and end-of-life processing.

The potential for thermal runaway leading to fire and explosion is considered a significant safety issue and has received much public attention following, for example, Tesla Model S fires and during the recall of Samsung Galaxy Note 7 smartphones[19].

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[13] https://acola.org/wp-content/uploads/2018/08/wp3-sustainability-evaluation-energy-storage-full-report.pdf - September 2019

[14] https://www.economist.com/the-americas/2017/06/15/a-battle-for-supremacy-in-the-lithium-triangle - accessed September

[15] https://www.wired.co.uk/article/lithium-batteries-environment-impact and http://www.liionbms.com/pdf/lithium_shortage.pdf - accessed September 2019

[16] https://www.washingtonpost.com/graphics/business/batteries/tossed-aside-in-the-lithium-rush/ - accessed September 2019

[17] https://www.washingtonpost.com/graphics/business/batteries/tossed-aside-in-the-lithium-rush/ - accessed September 2019

[18] https://www.foeeurope.org/less-more-140213 - accessed September 2019

The fire risks are well known and can be mitigated by appropriate battery design and installation, the use of a battery management system and adherence to end-of-life safety protocols [53][54].

Li-ion batteries are typically combined with a battery management system. The battery management system monitors the voltage of each battery cell when charging and discharging to prevent hazardous overcharge or excessive discharge.

There have been a number of fires at recycling plants and landfill sites where lithium-ion batteries have been stored or disposed of improperly[20].

Li-ion disposed of in landfill pose a fire risk to waste disposal workers and can shut down plants.

Batteries present chemical hazards due to the incorporation of corrosive, caustic or toxic chemicals. Rupture of a Li-ion battery can result in emission of gases that may contain carbon monoxide (CO), nitric oxide (NO), sulphur dioxide ($SO_2$) and hydrogen fluoride (HF)[55].

Electric shocks are a hazard posed by all battery types. This can be mitigated by insulating terminals and avoiding contact with conducting material. End of life batteries can carry residual charge and should be decommissioned and removed by trained personnel.

**Impacts on building owners and users**

Any small or medium sized business that losses the ability to serve its customers can cause immense reputational and financial damage. If an investment of a few thousand pounds or euros can help guarantee that the business will keep running, then it may well seem like an attractive return on investment.

Several major battery manufacturers such as Tesla, GE (General Electric) and LG Chem are moving into the home (or small building) energy storage market[21].

This could represent a significant step in making local, small scale wind and solar power generation more practicable. It could also enable buildings to operate in areas of the world where the grid is unreliable or non-existent.

At this stage small scale battery storage is expensive - a 10kWh Tesla battery (which could power a laptop for twenty days, or boil 100 kettles) will cost around £2,275 to buy – and likely to appeal only to small and medium sized businesses with healthy capex budgets or those willing to pay to make a green gesture[22].

Costs are predicted to fall over the coming years as market penetration increases and economies of scale are reached[23].

Another factor that could influence the market is regulation - requiring builders or building owners to make provision for storage, or a battery supplier willing to take a loss-leading initiative.

Safety concerns around battery systems may need to be addressed for building occupants given the number of well publicised fire risks reported for various types of battery technology such as laptops, vehicles and smart phones. [24]

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[19] https://www.bbc.co.uk/news/technology-37104753 and https://www.bbc.co.uk/news/business-38714461 - accessed September 2019

[20] https://www.bbc.co.uk/news/world-europe-guernsey-45059371 - accessed September 2019

[21] https://www.bbc.co.uk/news/technology-32545081 - accessed September 2019

[22] https://www.bbc.co.uk/news/technology-32545081 - accessed September 2019

[23] http://enerjiye.com/wp-content/uploads/2018/12/battery-market.pdf - accessed September 2019

[24] http://interface.ecsdl.org/content/21/2/37.full.pdf+html – accessed September 2019

The storing of a lot of energy within a very small space at a workplace may very well cause concerns.

Some building batteries may need to be located in purpose-built outdoor enclosures (due to the lack of space within the small buildings) making regular inspection difficult. This arrangement may also mean that users are prevented from taking advantage of power sockets, mounted on the front of some battery units, which provide mains power in the event of a power outage.

Alternatively, inverters, metering and batteries can be fitted in loft or roofing areas and building tenants may have no physical or authorised means to access them. High temperatures in lofts may also reduce the lifespan of battery systems and inverters.

Battery systems can have very different pre-set minimum (cut in) and maximum power (rated) output. Setting the battery inverter to operate only when building demand rises above a given threshold ensures that the battery is discharged only when savings exceed the energy required to operate the inverter thus improving system efficiency. However, this prevents very low energy consuming buildings from benefiting from the battery for much of the time. Some systems may not supply power until demand exceeds 300W. In contrast, some other systems only supply a maximum power of 430W, meaning high consumers will have only a small portion of their demand met by the battery at any one time[25].

Connectivity to external systems and monitoring platforms can be a significant challenge for building owners who may not realise that WiFi, 3G, 4G or GPRS connection is typically required for battery systems to operate properly and allow system management. Furthermore, some manufacturers require internet connectivity for the battery warranty to qualify.

The need for internet connectivity varies for different battery systems. Some systems providing basic functionality in the absence of WiFi whereas other systems may simply switch to a standby mode. When offline, the manufacturer is unable to detect that the battery is non-operational and resolve the issue[26].

Buildings located in areas of poor broadband connectivity should ensure that the battery system can access robust internet connection. Hardwired connectivity is the most reliable method but may be more costly and challenging to install than Wifi.  If Wifi is used, then signal strength at the intended location of the battery should be measured and routers should be left on continuously.

With respect to the RE-COGNITION project, remote monitoring/control of host site battery systems may be hindered at locations where Wifi outages are common or internet connectivity is not robust.

As building energy management technology becomes more complex for smaller and medium sized buildings those with technically savvy and attentive owners may benefit most from the savings offered by battery storage systems. Those unwilling, or unable, to dedicate time to ensure continued battery system operation may be at a disadvantage[56].

Many battery systems have unintuitive on-site displays. For example, many use an array of variously coloured indicator lights to indicate different health states. A recent report on the implementation of

[25] http://www.nea.org.uk/wp-content/uploads/2019/02/Best-Practice-Domestic-Batteries-FINAL-27-03-2019.pdf

[26] http://www.nea.org.uk/wp-content/uploads/2019/02/Best-Practice-Domestic-Batteries-FINAL-27-03-2019.pdf

domestic battery systems by National Energy Action found that battery indicators on some systems can be inaccurate and users may even be told to ignore them by product representatives[27].

Poor interpretability can lead to lack of confidence in the battery system and make critical information meaningless to system users with limited technical knowledge.

Some systems enable remote monitoring via 'online' portals or smart phone apps. These portals present battery data more visually, however, even this interface can be confusing or frustrating for system users who need only access infrequently or have limited technical knowledge.

Consumer confidence in the UK is emerging as some battery manufactures have 'signed up' to a customer protection scheme called the Renewable Energy Consumer Code (RECC) which aims to ensure the quality of the product and installation and provides a dispute resolution service if there is an issue with an installer[28].

The Microgeneration Certification Scheme (MCS) is a quality assurance scheme, whose website provides a list of accredited installers familiar with commissioning microgeneration systems[29].

Some battery system warranties allow for significant degrading of the battery during the warranty period, reducing usable capacity and end-user benefit over time. Ideally warranties should guarantee a certain number of cycles and that the battery keeps a certain amount of its capacity over the course of the warranty.
If the battery fails, there can be considerable expense associated with removing and shipping units to service points. Warranties providing on-site service can reassure owners that they will not be met with high carriage costs and insurance charges by couriers as lithium-ion batteries are regarded as hazardous materials.

Battery systems may also provide additional cost savings for users. As electric vehicle infrastructure matures the ability for an electric vehicle to not only charge its battery but also supply energy back to the grid when connected to a charging point is being tested and developed – a concept called Vehicle-to-Grid (V2G). Building owners with V2G charging units on site may therefore be able to purchase electricity directly from employee/customer vehicles in its carpark at rates lower than standard network supply prices. In return vehicle owners generate a revenue from the energy they elect to supply the building. Cheap V2G energy could be purchased and stored in the building battery system to help offset periods of low generation or high consumption.
Grid Services are a new concept at the small and medium building level. Multiple batteries can be aggregated together to provide a resource which can be sold to national grid services markets operated by DSOs, DNOs and national grid operators. Some manufacturers have their own platforms

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[27] http://www.nea.org.uk/wp-content/uploads/2019/02/Best-Practice-Domestic-Batteries-FINAL-27-03-2019.pdf

[28] https://www.recc.org.uk/

[29] https://www.microgenerationcertification.org/

and arrangements to allow battery owners to provide these services by agreeing to sell excess stored energy back to the grid when it's needed [57].

### Environmental impacts

The initial stages of the lithium-ion battery supply chain, including the extraction and processing of cobalt, graphite and lithium, has significant environmental impacts. Most of these impacts occur outside Europe, at different points along a complex supply chain.

Researchers are working on new battery chemistries that could replace cobalt and lithium with more common, environmentally friendly and less toxic materials. However, reducing the environmental cost is a complex issue. Use of a less durable, but more sustainable device for example could create a larger carbon footprint once transport and extra protective packaging are factored in[30].

### Cobalt

The majority of the world's cobalt is mined in the DRC where cobalt ores are mined in industrial and hand-dug artisanal mines. Both types of mines, as well as local smelters, contribute to environmental pollution.

Cobalt mining in the DRC has traditionally taken little control of the waste products from mines or smelters resulting in the contamination of land, water and air with heavy metals. Artisanal miners rinse cobalt ores in local water sources leading to water that is unfit for human consumption and agriculture[31].

Populations living around mines and smelting plants are also exposed to contaminants from the environment even if they do not work themselves in cobalt mining or refining. Cobalt concentrations in local drinking water, vegetables and fruit were shown to correlate with concentration of cobalt in the population. For children, dust and soil ingestion was identified as a major source exposure [58].

Cities such as Lubumbashi and Likasi face serious air pollution from the many trucks that travel to and from the mines throughout the day. Chronic exposure to these dusts can lead to severe lung diseases[32].

### Lithium

In Australia and China Large quantities of waste rock are created from the mining of lithium from hard rock spodumene. The process is very energy intensive and uses large volumes of water.

The largest lithium brine resources are located in the 'lithium triangle' between Argentina, Bolivia and Chile. In Argentina's Salar de Hombre Muerto, locals claim that lithium operations have contaminated streams used by humans, agriculture and livestock. In Chile and Argentina, local communities claim that lithium mining has left mountains of discarded salt and contaminated water sources used for agriculture and livestock[33].

To produce lithium from brines, holes are drilled into the salt flats to pump brine to the surface where it is concentrated into lithium carbonate in evaporation ponds. The evaporation process uses large

[30] https://www.nature.com/magazine-assets/d41586-018-05752-3/d41586-018-05752-3.pdf
[31] https://www.oeko.de/oekodoc/1294/2011-419-en.pdf - accessed September 2019
[32] https://goodelectronics.org/wp-content/uploads/sites/3/2016/04/Cobalt-blues.pdf
[33] https://www.foeeurope.org/sites/default/files/news/foee_report_-_less_is_more.pdf

volumes of water and chemicals used during the process can harm the environment if released through leaching, spills or emissions into the air. The mining of lithium could have impacts on human health and biodiversity due to the decrease in available freshwater and contamination of water courses[34].

In Bolivia, which has the world's largest lithium reserves, there is local resistance to a planned lithium mining development in the Salar de Uyuni because of the high-water use and environmental impacts of ongoing silver mining in the area[35].

### Graphite

China is the major producer of graphite used for batteries. Mining occurs mainly in remote Heilongjiang Province in the northeast of the country[36]. Dust from the mines contaminates the surrounding air and water and impacts the health of local residents.

Air pollution from graphite occurs if there are inadequate controls to keep the fine graphite powder from becoming airborne. The dust can irritate the respiratory system and cause lung diseases.

Residents living near mines have reported polluted drinking water and damages crops. Chemicals during purification, such as hydrofluoric acid, can cause water pollution if they are discharged or leak into local water sources[37].

Research in Australia found that only 2% of the country's 3,300 tonnes of lithium-ion waste was recycled. Unwanted MP3 players and laptops can end up in landfill, where metals from the electrodes and ionic fluids from the electrolyte can leak into the environment[38].

Manufacturers are secretive about what goes into their batteries, which makes it harder to recycle them properly. In the absence of an economic driver or clear policy directives industry are unlikely to invest in local end-of life solutions for recycling and reusing storage batteries.

## Energy conversion

### Wind turbines

All energy supply options can have adverse environmental impacts including the potential to reduce, fragment, or degrade habitat for wildlife, fish, and plants. Furthermore, spinning turbine blades can pose a threat to flying wildlife like birds and bats [59].

Among the wildlife negative effects there is also the human factor that is affected by the use of wind turbines. Even though it's a popular form of energy generation, the construction of windfarms is not universally welcomed for the noise they produce and often for aesthetic reasons [60].

Potential site-specific impacts on birds or bats can be avoided and minimised by careful planning and sitting, or else mitigated or compensated. In fact, wind energy is one of the cleanest, most environmentally friendly energy sources because of its long term positive impacts such as: reduces the thread posed by climate change by emitting no greenhouse gases; it has one of the lowest $CO_2$

[34] https://www.foeeurope.org/sites/default/files/news/foee_report_-_less_is_more.pdf

[35] http://www.liionbms.com/pdf/lithium_shortage.pdf

[36] http://www.northerngraphite.com/_resources/media/Graphite-feature-july-2010.pdf

[37] https://www.washingtonpost.com/graphics/business/batteries/graphite-mining-pollution-in-china/

[38] https://www.theguardian.com/environment/2018/jul/17/only-2-of-lithium-ion-batteries-in-australia-are-recycled-report-says

emissions and energy used through its life cycle; it emits no air pollutants; it emits no micro particles; it uses almost no water and turbines are almost fully recyclable [61].

### Photovoltaic (PV) Panels

Photovoltaic technologies and solar inverters are not known to pose any significant dangers to their neighbours. Due to the reduction in the pollution from fossil-fuel-fired electric generators, the overall impact of solar development on human health is overwhelmingly positive [62].

However, some toxic materials and chemicals are used to make the photovoltaic (PV) cells that convert sunlight into electricity. Some solar thermal systems use potentially hazardous fluids to transfer heat. Leaks of these materials could be harmful to the environment[39].

There are a number of photovoltaic technologies, each one posing a minimal risk to humans and animals, the technologies and their risks are documented below:

### Crystalline silicon PV

They account for 90% of PV panels installed today, being, more or less, a commodity product. Well over 80% of their weight comes from the tempered glass front and the aluminium frame, both of which are common building materials. The active, working components of the system are silicon photovoltaic cells, the small electrical leads connecting them together, and to the wires coming out of the back of the panel. The PV cell itself is nearly 100% silicon which is the most common element in the Earth's crust. The silicon is obtained by high temperature processing of quartz sand that removes its oxygen molecules. The refined silicon is converted to a PV cell by adding extremely small amounts of boron and phosphorus, both of which are common and very low toxicity. There are also very small amounts of other benign materials and lead. However, the very limited amount of lead in the PV panels poses very little to no health hazard even in the worst-case scenarios[40].

### Cadmium telluride (CdTe) PV

Questions about the potential health and environmental impacts from the use of this PV technology are related to the concern that these panels contain cadmium, a toxic heavy metal. However, scientific studies have shown that cadmium telluride differs from cadmium due to its high chemical and thermal stability[63].

Researchers have shown that the tiny amount of cadmium in these panels does not pose a health or safety risk [64].

Similar to silicon-based PV panels, CdTe panels are constructed of tempered glass front, clear plastic encapsulation layers and a rear strengthened glass backing.

### CIS/CIGS and other PV technologies

Copper indium gallium selenide PV technologies, often referred to as CIGS, is the second most common type of thin-film PV panel but a distant second behind CdTe. CIGS cells are composed of a thin layer of copper, indium, gallium and selenium on a glass or plastic backing. None of these

[39] https://www.pveducation.org/pvcdrom

[40] http://svtc.org/

elements are very toxic, although selenium is a regulated metal under the Federal Resource And Recovery Act (RCRA)[65].

Notably, these panels are RoHS compliant, thus meeting the rigorous toxicity standard adopted by the European Union [66].

### Electromagnetic Fields (EMF)

PV systems do not emit any material during their operation; however, they do generate electromagnetic fields, sometimes referred as radiation. EMF produced by electricity is non-ionizing radiation, meaning the radiation has enough energy to move atoms in a molecule around, but not enough energy to remove electrons from an atom or molecule or to damage DNA. Modern humans are all exposed to EMF throughout our daily lives without negative health impact. Since the 1970s, some have expressed concern over potential health consequences of EMF from electricity, but no studies have ever shown this EMF to cause health problems[41][67][68].

### CHP

Combined heat and power (CHP) refer to any system that simultaneously or sequentially generates electricity and recovers and re-uses the thermal energy by product of this process.

CHP is one of the most economical methods of reducing greenhouse gasses, a role which is recognised officially by the European Union, among the use of RES [69].

At minimum, cogeneration will increase fuel efficiency by replacing separate devices producing either electricity or thermal energy with a single device providing both. Thus, less fuel would have to be burned to produce the same energy and, as a consequence, reducing the emissions. Other advantages of CHP include: Savings on total energy costs as a function of electricity and heat saving; high level of fuel flexibility; independence and security of power supply; improving the energy performance of buildings; supporting the electricity grid by compensating the intermittency of RES.

## Electric Vehicle charging

In general, the operation of electric vehicle (EV) supply equipment doesn't have a significant impact on human life and organization. The impact of EV supply equipment on human health is indirect: it enables deployment of electric vehicles and thus a wide acceptance of electromobility by citizens and companies with all its benefits for the environment and society, such as:

- Reduction of GHG emissions: during the operation (driving) the EVs doesn't emit any GHG. The indirect GHG emission is due to production of electric energy needed for propulsion of EVs. Obviously, the optimum result in terms of GHG emissions from transport is achieved if the electric energy for EVs is produced by power plants which are not using fossil fuels. In the opposite case the EVs cannot be treated as "zero-emission" vehicles; however, their contribution to GHG emissions is lower than from conventional vehicles due to higher energy efficiency rate (well-to-wheel) of electric energy production compered to internal combustion engines;

[41] https://www.who.int/peh-emf/publications/facts/fs322/en/
https://www.who.int/peh-emf/publications/facts/fs299/en/

- Reduction of other air pollutants: Harmful emissions: EVs do not produce any fine particles or other emissions, therefore they do not cause respiratory health issues or increase cancer incidence. Even if the electric energy is produced from fossil fuels, the process of production enables more quality purification (filtering) of exhaust gases than internal combustion engines. In this way the general air (and also soil) quality is improved, especially in the vicinity of roads with heavy traffic;
- Soil and water pollution: the EVs engines and appurtenant components contain no or a very limited quantity of oil and lubricants compared to conventional vehicles; the engine oil and lubricants disposed into the water and soil is therefore negligible;
- Reduction of noise: the noise caused by traffic is one of the growing problems in densely populated areas that affect the human health. EVs' engines produce a low-level noise, significantly lower than the conventional engines.

### Economic sustainability

The use of EVs greatly contributes to a stronger European independence from traditional energy supplies, as the market share for diesel and petrol will decrease substantially in the coming years.

Around 1,740 million barrels of oil per year could be saved by 2050 in Europe with the transition to a zero-emission passenger car fleet, the equivalent of €78 billion at the price of $45 per barrel.

While there has been much discussion surrounding the impacts of electric vehicles on the electricity distribution grid, we believe that with the right approach and with consumer charging incentives, that foreseen impact will be manageable.

Taking the advantages of smart charging of EVs in Germany would to a large extent offset investment of more than €2 billion per year in 2050. This is also consistent across countries in scenarios with high EV deployment[42].

### Human sustainability

According to the World Health Organisation (WHO), air pollution is the biggest environmental risk to health in Europe. Moreover, the European Environment Agency (EEA) estimates that more than 1.000 premature deaths occur each day due to air pollution, of which road transport continues to be a major contributor of. For instance, in 2015, it was responsible for 39 % of atmospheric nitrogen oxides (NOx) and 11 % of particulate matter (PM10 and PM2.5) emissions.

Car free days in cities like Paris and Brussels have demonstrated a radical drop in NOx pollutants within hours of the ban being effective. The French Senate found that air pollution costs France €101.3bn a year in negative health, economic and financial consequences. It said illnesses created or worsened by pollution included Alzheimer's disease, heart disease, respiratory disease and some cancers, and that air pollution is also linked to fetal development problems. The report also estimated

[42] https://avere.org/economic-sustainability/

that pollution caused up to 45,000 premature deaths in France a year, from asthma, chronic bronchitis, heart attacks, lung cancer and strokes.

Traffic noise makes the atmosphere of modern cities increasingly unbearable. Thousands of traditional combustion-engine powered vehicles generate significant noise which degrades the quality of life within cities. For example, around 100 million people across Europe are exposed to average sound levels of 55 dB or higher during the day, evening and night for road traffic noise.

The WHO acknowledged in a 2011 study the impact of noise in cities as a public health problem. According to the study, 1.8% of heart attacks in high income European countries are attributed to traffic noise levels higher than 60dB. An EV on the other hand is silent at city speeds and silent during acceleration[43].

### Environmental sustainability

It is clear that the transition to electrification and the promotion of electric vehicle uptake specifically, plays an important role in the reduction of emissions and air pollution. On a global scale, the advancement of electromobility can help countries achieve their overall climate change objectives, such as those agreed upon at COP21 and those envisioned in the European Commission's proposed 2050 Long Term Climate Strategy announced in 2018.

It is expected that the transport sector will deliver a 60% reduction in GHG emissions in the EU by 2050. Whereas it is predicted that reaching the COP21 goal of limiting temperature to 1.5°C, will require a complete de-carbonisation of the transport sector by 2050.

EAFO studies show that with a transition to a 100% zero-emission vehicle car fleet by 2050 it is possible to achieve an additional reduction 2.2 to 3.9 gigatonnes of cumulative CO2 emissions in 2020 and 2050 compared to existing EU targets. As the European power industry has committed to near 100% carbon neutral electricity production in Europe by 2050, the net "Well to Wheel" GHG emissions reduction from transport can be expected to be even higher.

On a life-cycle basis, EVs are already very competitive regarding CO2 emissions (compared to other propulsion modes). This CO2 intensity will further decrease in the future, based on the increasing share of renewables in the energy mix. In a full life-cycle, taking into account the current European electricity mix, electric vehicles emit two times less carbon dioxide (CO2) in comparison to diesel engines. This can be even 4 times less if we take as an example the Belgian electricity mix. If cars were driving on sustainable electricity, carbon dioxide emissions could be further reduced by a factor of 15.

[43] https://avere.org/human-sustainability/

With the current European average power mix and its emissions of 275.9g CO2/ KWh, electric vehicles emit less than 50% of what an average internal combustion engine car emits today. The WTW emissions of EVs will continue to fall, as the European power sector de-carbonises by 2050.

## Electric vehicle charging stations

There are three basic ways to charge an electric vehicle: plug-in charging, battery swapping or wireless charging.

### Plug-in charging

Plug-in charging is used by the vast majority of current EVs in Europe. Vehicles are physically connected to a charging point using a cable and a plug. Plug-in charging can occur wherever charging stations are located: at homes, in public streets or on commercial or private premises.

Electric vehicles can, in general, be charged using normal household sockets, but this is slow because normal domestic sockets provide only a low amount of electric current. It can therefore take approximately eight hours for a typical charge. This can be quite suitable for overnight charging. Faster plug-in charging requires specialised infrastructure. To date, most public plug-in stations established at a city, regional or national level offer only normal-speed charging.

### Battery swapping

Battery swapping involves replacing a used battery with a fully charged one at a special swapping station. This offers a rapid way of quickly 'recharging' a vehicle. At present, no major providers in Europe offer battery swapping. Several barriers have prevented battery-swapping technology from becoming widespread, including the lack of electric vehicle models that support battery swapping, no standard type or size of battery, and the high cost of developing the associated charging and swapping infrastructure.

### Wireless charging

Wireless charging, also known as induction charging, does not require a fixed physical connection between the charging facility and the vehicle. Instead, the system creates a localised electromagnetic field around a charging pad, which is activated when an electric vehicle with a corresponding pad is positioned above it. The wireless method currently operates at only a selected few pilot locations and is yet to be used commercially. Examples of inductive charging pilot projects include wireless charging for buses at bus stations in Belgium, Germany, the Netherlands and the United Kingdom, as well as some pilot testing for users of electric cars in Sweden.

### The different types of plug-in charging

There are different ways in which battery electric vehicles or PHEVs can be charged via plug-in charging. Four modes of charging technology are commonly available. Each of them can involve different combinations of power level supplied by the charging station (expressed in kW), types of electric current used (alternating (AC) or direct (DC) current) and plug types. As electrical power grids provide AC current, and batteries can store only DC current, the electricity provided by the grid to the electric vehicle first needs to be converted. The conversion can be done either by an on-board AC/DC converter inside the electric vehicle or by a converter integrated into the charging point itself. Hence, AC charging is sometimes referred to as 'on-board charging'. DC fast-charging stations have integrated converters, so the charging station itself converts AC electricity from the grid into DC electricity for the electric vehicle. The power level of the charging source depends on both the voltage and the maximum current of the power supply. This determines how quickly a battery can be charged. The power level of charging points ranges widely, from 3.3 kW to 120 kW. Lower power levels are typical of residential charging points.

Mode 1 (slow charging): allows vehicle charging using common household sockets and cables. It is commonly found in domestic or office buildings. The typical charging power level is 2.3 kW. Household sockets provide AC current.

Mode 2 (slow or semi-fast charging): also uses a non-dedicated socket, but with a special charging cable provided by the car manufacturer. A protection device that is built into the cable offers protection to the electrical installations. It provides AC current.

Mode 3 (slow, semi-fast or fast charging): uses a special plug socket and a dedicated circuit to allow charging at higher power levels. The charging can be either via a box fitted to the wall (wall box), commonly used at residential locations, or at a stand-alone pole, often seen in public locations. It uses dedicated charging equipment to ensure safe operation and provides AC current.

Mode 4 (fast charging): also sometimes referred to 'of-board charging', delivers DC current to the vehicle. An AC/DC converter is in the charging equipment, instead of inside the vehicle as for the other levels. One disadvantage of high-power, fast charging is that the stronger currents mean that more electricity is lost during transfer, i.e. the efficiency is lower. Moreover, fast charging can decrease battery lifetime, reducing the number of total charging cycles. Fast DC charging points are also around three times as expensive to install as a simple AC charger, so many users are reluctant to invest in the additional costs. While some new electric vehicle models are provided with a DC charging facility, others require the purchase of an additional charging device.

Electricity can be distributed using single-phase or three-phase systems. Households commonly use single-phase power for lighting and powering appliances. It allows only a limited power load. Commercial premises commonly use a three-phase system, as it provides higher power[44].

Impacts of operation of EV charging infrastructure on human health

[44] https://www.eea.europa.eu/publications/electric-vehicles-in-europe/download

These impacts are regulated with standards related to electromagnetic compatibility, electrical protection of switchgear assemblies, insulation coordination and degrees of protection provided by enclosures (IP code).

Impacts of operation of EV charging infrastructure on electricity systems

At the moment the impact of EV charging on electricity system is low, due to low share of EVs in the vehicle fleets. The electrical grid infrastructure will have to be adapted for larger number of electric vehicle chargers and even now it is possible that the infrastructure at some point is not good enough to enable the installation of charging stations[45].

In order to enable the EV charging to operate safely within the network and adapt the charging load to external conditions (e.g. in final customer's internal network - where the charging stations are connected to, in microgrid or energy community, in distribution and transmission systems, or on the energy market) the charging station must be able to communicate with these external systems (home, building & factory energy management systems, system operators' control centres, energy market) to acquire information about their needs, and with the EV to control the charging load of each connected EV. Such integration of operation of EV charging infrastructure with external systems is called "smart charging". Smart charging can contribute to wider adoption of EVs by consumers, reduce EV charging costs, alleviate the impact of EV charging on power grids operation and enables better integration of renewables into the electricity systems. Smart charging is recognised as a key element in development of functionalities related to EV charging also by the Platform for electromobility[46]:

Smart charging technologies (Grid to Vehicle available today and possibly Vehicle to Grid in future) make EVs a valuable asset in the electricity value chain while reducing the costs of charging to EV owners. In terms of available electric capacity, the system can cope with an extensive electrified fleet. But a fully electrified fleet would still have impacts on local load at certain times and some local or regional strengthening of the grid would therefore be needed. However, smart charging of EVs can also reduce investments in grid capacity going forward.

While parked (90% of their lifetime), thanks to smart, controlled charging, EVs can provide flexibility services … like (i) "valley filling" (shifting consumption to times when energy is under-utilised), (ii) "peak shaving" (avoiding charging or sending power back to the grid when demand is high) and (iii) ancillary services (voltage control, frequency regulation) at system level and at local level.

**Smart charging is essential for a cost-effective energy transition and for facilitating consumers' adoption of EVs.** Smart charging leads to significant $CO_2$ savings by avoiding the use of gas- and coal-powered peak generation power plant and enabling a better integration of renewables into the electricity system. It can also reduce the cost of charging as it provides consumers with an opportunity to charge off-peak hours and benefit from the energy stored in their batteries.

**Normal power charging (<20 kW) offers the greatest opportunity for demand-response and smart charging,** as it accounts for around 90% of the energy charged by an EV. As it is expected that many people will connect their vehicle after work in the evening, which will further increase the demand for

[45] https://www.sciencedirect.com/topics/engineering/vehicle-to-grid

[46] https://www.platformelectromobility.eu/

electricity at evening peak times, smart charging can bring great benefits by postponing the moment of charging to a time of low demand on the grid, e.g. during the night. Such a shift will not limit the user's comfort, as the vehicle is generally parked for a much longer time than it takes to recharge the battery, so there is enough flexibility that can be exploited.

**Potential for modulation on high power charging points (>22 kW) is fairly limited.** First, high power charging accounts for only 10% of the energy charged by EVs and hence offers a relatively limited market overall. Also, high power charging happens in a much more equally distributed way during the day, i.e. the modulation of high power charging would offer much less potential to ease impact on the grid. Finally, the fundamental aim of high power charging is to allow for a rapid refill where parking time is limited to the recharging time of the vehicle[47].

## Software

Power systems are among the most complex and critical infrastructures of a modern digital society, serving for its economic activities and security. It is therefore in the interest of every country to secure their operation against cyber risks and threats [70], as stated in the report of the European Commission's Smart Grids Task Force, as well as in the 'Cyber Security in the Energy Sector' report [71]published in 2017 by the Energy Expert Cyber Security Platform (EESCP).

When we talked about energy safety, there are 5 elements that may be considered[48]:

- Safety - safely supplies energy to end user;
- Security - maintains power in a malevolent environment;
- Reliability - maintains power when and where needed;
- Sustainability - it can be maintained for mission duration;
- Cost Effectiveness - produces energy at lowest predictable cost.
-

The focus of the RE-COGNITION project consists on the development of the **Cross-Functional RES Integration Platform**, including the **Automated Cognitive Energy Management Engine** (ACEME) along with an **intelligent Gateway** (iGateway). This is a software tool for optimally harnessing the energy generated from each of the available energy resources.

On top of the above and for assisting the planning phase of relative solutions' integration, **the Building Energy PLant Planning Tool** (BE-PLATO) will be developed for aiding building stakeholders with optimal decision making and enhancing their awareness of available RE-based systems.

The ACEME will be a promising software tool that may provide predictive information and recommendations to all stakeholders (e.g., utilities, suppliers, and consumers) regarding the optimization of their power utilization. It may also offer services like intelligent appliance control for energy efficiency and better integration of RES to reduce carbon emissions [72]. It can be regarded as a "system of systems" that involves both information and communication technology (ICT) and electricity system operations.

[47] http://www.platformelectromobility.eu/wp-content/uploads/2016/11/Executive-Summary-Platform-Position-Electric-Infrastructure.pdf

[48] https://www.osti.gov/servlets/purl/1116652

ICTs can improve the operational performance of electric power systems but may also unintentionally expose electric power systems to cyber threats when there is a lack of proper security management [72].

Threats from individual or groups have the potential to cause harm and can be characterized by their level of access, motivations, and capabilities. Threats can be insiders, hackers, terrorists, organized crime or nation states. Because of the knowledge of assets and ready access to these assets, insider attacks can do substantial damage.

Cyber incidents can even give rise to catastrophic impacts on electric power system operations. For example, Table I lists the massive electric power interruptions resulting from cyber incidents [73][74] [75] which demonstrate that cyberattacks can potentially trigger a widespread blackout in practical electric power systems [76].

Table 4 Power Outages Related to Cyber Incidents [76]

| Event | Cause | Consequence |
|---|---|---|
| 2003 Northeast Blackout | Alarm system failure due to a software bug | More than 50 mil. customers lost electricity |
| 2003 Italy Blackout | Cascading failures between power and communication infrastructures | About 56 mil. people across Italy were affected |
| 2007 Arizona Blackout | Unexpected activation of the load shedding program | About 100.000 customers lost 400MW load |
| 2008 Florida Blackout | Disabled relay protection during diagnostic process | About 1 mil. customers lost 3.650 MW load |
| 2011 Southwest Blackout | Monitoring equipment failure at a substation | Around 2.7 mil. customers lost electricity |
| 2015 Ukraine Blackout | Remote cyber intrusions after the malware installation | Approx. 225.000 customers lost electricity |

A system that is exposed to cyber threats has its own cyber vulnerabilities. Table II summarizes the most common cyber vulnerabilities of a smart grid. As cyber–physical systems, smart grids not only inherit common vulnerabilities from the information technology (IT) domain (when we refer to a specific software), but also must face unique vulnerabilities specific to their operational characteristics [76]. In practice, communication technologies and networking components retain the same vulnerabilities as those used in the IT domain. However, field devices and software applications have their specific vulnerabilities which depend on the smart grid design and configuration [76].

Table 5 Most Common Cyber Vulnerabilities in Smart grids [76]

| Domain | Common Vulnerability |
|---|---|
| Application Software | Poor Code Quality |
| | Inadequate Configuration Management |
| | Poor Permissions and Access Management |
| | Inadequate Patch Management |
| | Inadequate Data Integrity Checking |
| | Inadequate Error Handling |
| | Inadequate Database Protection |

| | |
|---|---|
| Communication Network | Inadequate Segregation and Segmentation |
| | Inadequate Access Control |
| | Weak Intrusion Detection and Prevention |
| | Weak Encryption Mechanism |
| | Inadequate Sensitive Data Protection |
| | Inadequate Network Monitoring and Auditing |
| | Inadequate Anomaly Tracking |
| Field Devices | Unprotected Physical Access |
| | Improper Device Configuration |
| | Inadequate Firmware Protection |
| | Lack of Tamper – resistance Hardware |
| | Weak Authentication and Authorization |

Considering the cyber incidents that were presented above, the cybersecurity of a smart grid software ought to meet three fundamental requirements [77]: availability, integrity, and confidentiality, as stated below:

- *Availability* means guaranteeing that data is accessible and timely [78];
- *Integrity* refers to assuring that data is trustworthy and accurate. The authenticity and consistency of data should be retained over its entire lifecycle, including collection by sensors, transmission via wireless media, analysis in application servers, etc. Data should always represent the actual information under all operating conditions[78];
- *Confidentiality* refers to protecting data from being accessed and comprehended by unauthorized parties[78].

The above cybersecurity requirements are differentiated from those in the traditional IT domain. The IT security is focused on ensuring the anonymity and confidentiality for preserving user privacy, whereas the primary focus of cybersecurity in smart grids is to retain the quality and the continuity of power supplies for keeping the lights on [76].

When we refer to the cybersecurity for renewable energy, there are three distinct levels[49]:

- *Cyber Security at the Component Level* [45]*;* this means that each control with physical or cyber access presents an intrusion point. Access must be controlled, and data integrity must be maintained at each accessible point.
- *Cyber Security at the Generation Level*[45]*;* e.g. Solar dish/trough/panel sensor, Wind control stations, Field weather and environmental data sensors, Networking architecture and routers.
- *Cyber Security at Interconnected Levels* [45]; Several issues should be considered regarding the interconnection of numerous renewable energy technologies:
- Diverse systems (hardware, software);
- Numerous end nodes and access points at all locations across the grid;
- Number of data sources and sensors greatly increased;
- The need to protect data across widespread areas (encryption).

There are a few *Cyber Security Elements* which must be taken into consideration in *Renewable Energy Systems* [45]:

[49] https://www.osti.gov/servlets/purl/1116652

- Cyber and Physical Access Control;
- Authentication;
- Intrusion Detection and Anomaly Detection;
- Data Encryption;
- Secure Protocols;
- Secure Application Code;
- Secure/Patched Operating Systems;
- Life Cycle Maintenance and Scalability;
- Operational policies and procedures that support human;
- Interaction with systems;
- Emergency Response Plans;
- Periodic Security Assessments.

An integrated risk analysis approach is very important for Cyber Security.

#### Cyber Security at Control Systems

Control design must ensure expected smart grid performance meets standards for power quality, voltage, frequency, protection. Also, they must protect the data and the functionality associated with these.

The used controls are:

- Automated grid management and control - frequency, voltage, load management;
- Supervisory control - human-in-the-loop grid management
- Specific channels dedicated to coordination between relays (also automated, time sensitive on the order of cycles)
- Configuration management – remote device, (re)configuration, downloading fault data, engineering configuration and management
- Connections to other systems with building systems for efficiency/load management.

Characterizing security threats to process control systems on the electric grid should consider:

- Implication of danger (i.e., what may a hacker do?)
- Source of that danger (i.e., who is the hacker?)

# 6 Safety and Security

This section presents a review of the safety and security aspects regarding the equipment placement, operation limits, robustness against the elements as well as compliance with regulations regarding installation of equipment on built/urban environments.

## Thermal Energy Storage

Safety and security aspects relating to the thermal storage unit proposed in this project are limited. This equipment does not have electrical connections, does not use combustion, its operating temperature is below 100 °C and its constituent materials are not flammable, nor toxic and neither corrosive. It constitutes an additional component for the heating system, whose hydraulic circuit has different pressures depending on the technology generating the thermal energy. Therefore, the most important rule to comply with is the European Directive 2014/68/UE[50] (also called PED), which "should apply to pressure equipment subject to a maximum allowable pressure PS greater than 0,5 bar" [79].

The equipment placement requires enough space for installation manoeuvres and successive inspections. Furthermore, depending on the component dimension, the supporting floor must be able to sustain its weight, which can be considerable for larger buildings.

There are operation limits regarding the maximum water flow in the tubes inside the tank, even though this issue is present only in case of an incorrect design which does not take into consideration the rest of the hydraulic system. A further limit regards the number of cycles before the degradation of the phase change material (PCM), which varies case by case. However, it mainly deals with the unit performance and doesn't have consequences on safety.

Summarising, the thermal storage based on PCMs is an additional and passive component for the heating system, therefore its safety implications are circumscribed.

## Building Integrating Photovoltaic (BIPV)

European BIPV standard EN 50583:2016 [80] constitutes the basis to identify "basic requirements" for BIPV plants. This standard, which is currently the reference also at Italian level, includes main requirements to ensure safety and durability of PV systems. The European Union Construction Products Regulation CPR 305/2011 [81] as well, set essential mechanical resistance and stability requirements and several testing and assessment methods used to verify the fulfilment of these requirements [11]. In many applications, BIPV requires higher load resistance and structural rigidity than standard PV modules and must provide so-called "post-breakage integrity", meaning that a broken BIPV must remain safe for a predefined period of time, even after the damage [11].

In many countries PV installation guidelines have been published and often they have become codes with which installers must comply. The Authority having jurisdiction (AHJ) for fire safety in Italy, in 2012 has released a Guideline in order to assess and mitigate the risk of fire when a PV system is put in place on a building as a façade or as a roof [82]. The guidelines were developed with a non-prescriptive approach, in accordance with the Regulation of the Construction Product – CPR Regulation (EU) n.305/2011 [81], the assessment and mitigation of the fire risk as a result of a PV plant installation on a building should be performed according to basic requirement n. 2 of construction work: "Safety in case of fire". In general, during a fire involving a building with a PV system, firefighters must take additional measures. DC cable insulation may melt and cause a DC arc flash. The panels themselves will continue to produce power as long as the sun is shining and possibly even at night, when bright public lights or fire lights are present.

In more detail, some constraints [83] should thus be considered in PV installation: the guidelines require a distance between PV module and skylights no less than 1m. That statement is a useful reference for skylights, domes, natural smoke and heat exhaust ventilators (NSHEV) and similar, except for the possibility to use the risk assessment tool for identifying other solutions in compliance with the safety basic requirements of the EU Regulation 305/2011. In order to mitigate the fire

[50] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014L0068&from=EN

spreading of a PV fire on the roof and, in particular, the spreading between adjacent fire compartments, a distance of 1m is also required among PV module sand vertical projection of fire-resistant compartment walls onto the ceiling (wall/ceiling slab intersections). All the geometrical constraints are summarized in the following figure:

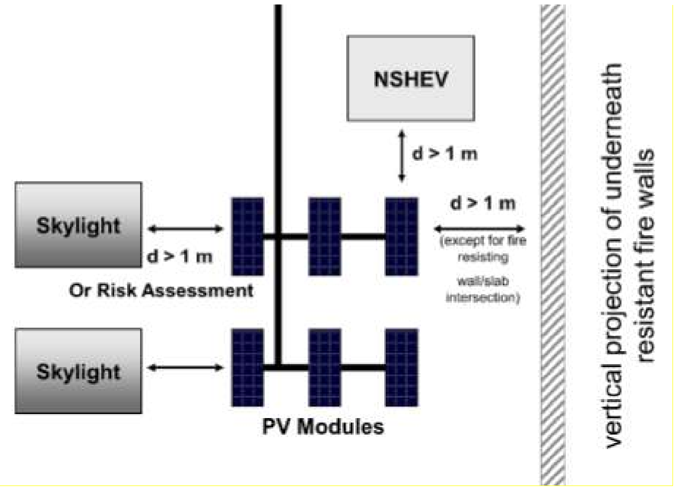


Figure 4 Italian guideline distance requirements to the smoke, venting systems and fire wall/slab intersections

## Hybrid Solar Cooling

The Hybrid Solar Cooling system is mainly composed of an adsorption air conditioning unit (AACU) and a solar thermal collector installation that produce the thermal energy to regenerate the adsorbent material. The solar thermal collectors do not constitute prominent health or safety risk for users. The main issues are related with the lack of services in case of failure of the module and water leakage that can damage structural components of the buildings. The ISO 9806:2017 [84] clarifies a set of reliability and durability tests for solar thermal collectors in order to guarantee a continuous operation of the system. Extreme weather and working conditions are simulated to ensure technical robustness and trustworthiness. Moreover, with the increase of minimum share of RES production in new and renovate buildings, such standards guarantee proper quality products also against constructors and companies that are likely to install cheap modules to contain the cost producing financial and environmental issues for users [85]. Solar collectors, as well as PV modules, must face regulations about roof occupation and aesthetics that vary from country to country and even at regional and urban scale. Usually, the solar system is combined with a thermal storage in order to match the production and the energy request. Thermal energy storages, with their implications, have been discussed in the Thermal Storage paragraphs (*Thermal Energy Storage* ).

The AACU is composed by a standard vapor compression cycle, as in most of the air conditioning units, plus an adsorbent material devoted to handle the moisture. Regarding the vapor compression there are international regulation for refrigerants, such as the Montreal protocol, and pressure equipment limitations. The first one is pushing towards low GWP and ODP potentials refrigerant while the second one pose limits on charging mass, toxicity and flammability of the refrigerants [86].

Finally, the absorbent material. Most of the liquid desiccant materials are irritant and corrosive while for solid ones, they have to be produced following proper procedures in order to avoid residuals, as solvent, in the final products. There are different types of material that can be used for adsorption. Some of them can be dangerous i.e. CaCL2 or BrLt2, but for our application, we will use materials such as Silica gel or Zeolite that do not present any major hazards for workers or users.

## Wind Turbines

Rules applying for Windcity' SWT Technical requirements are IEC 61400-2:2013 Wind turbines - Part 2: Small wind turbines..

Other rules & requirements, or codes requiring electrotechnical analysis for safety and security are:

- Electromagnetic compatibility requirements from Comité International Spécial des Perturbations Radioélectriques (CISPR; English: International Special Committee on Radio Interference),
- Electrical security for power converters requirements as per IEC 62477, and
- Grid Code and System Integration, including the EN 50438 to EN 50549 regulation transition and discussion about national codes across EU towards a common code,

Concerning integration of the SWT into the building, and therefore the building response to vibrations, and evaluation of their effects on structures, the [ISO 4866] applies to this project.

## Energy Storage Systems

Energy storage is subject to many different regulatory frameworks across EU Member States. As such there is no consistency amongst the Member States on the way storage is treated in the energy system. For example, in some Member States battery storage facilities pay both consumer and producer grid fees but in others only producer fees are paid[51].

The lack of a clear definition for energy storage in European regulatory framework has resulted in a lack of coherence in the classification of storage facilities across Member States. The new electricity Directive and Regulation, which replaces the Electricity Directive (2009/72/EC) and the Electricity Regulation (EC/714/2009), is part of the EU's Clean Energy for All Europeans legislative package. It formally recognizes the role that energy storage plays in EU power markets and Member States will be expected to implement the directive into national law within the next two years[52].

Currently most Member Sates classify energy storage systems as a form of generation[53].

Connection of new generating equipment (i.e. battery storage) to a European distribution system will need to comply with the requirements from the European Connection Code: Requirements for Generators (RfG).

In general, within each European country local Distribution Network Operators (DNO) or Distribution System Operators (DSO) are responsible for the local distribution network supplying electricity homes

[51] https://ec.europa.eu/energy/sites/ener/files/documents/swd2017_61_document_travail_service_part1_v6.pdf

[52] https://europa.eu/rapid/press-release_IP-19-1836_en.htm

[53] https://www.store-project.eu/documents/results/en_GB/european-regulatory-and-market-framework-for-electricity-storage-infrastructure

and businesses. In order to manage the networks safely and efficiently, battery installations must meet engineering standards.

In the UK, DNOs categorise battery storage as non-intermittent generation as set out in Appendix 1 of the DNO distribution charging statements and as such, will be required to comply with one of two Engineering Recommendations (ERECs) G98 and G99[54].

EREC G98 relates to the connection of microgeneration i.e. type tested small-scale embedded generators (up to 16 a per phase) in parallel with public low-voltage distribution networks (3.68 kilowatts (kW) on a single-phase supply and 11.04 kW on a three-phase supply.

EREC G99 relates to the connection of generating plant to the distribution systems of licensed distribution network operators where generation is above 3.68kW and/or >230v.

Type testing certification applies to generation devices (e.g. batteries) rated to ≤50 kW which have been tested to ensure that the design meets relevant technical and compliance requirements for the Engineering Recommendations and that the manufacturer declares that all 'like' generation units produced will be built to the same standards and perform in the same way.

The advantage of type testing and the use of fully type tested generation devices in installs is that it tends to simplify the connection process and reduce commissioning test requirements. As a result, interactions with the DNO should be made simpler and cheaper.

For EU member states there will be numerous codes, standards and other sources of information on the installation and operation of energy storage systems. A full description of these for each Member Sate would be beyond of the scope of this report but those for the UK are detailed.

Standards for overall battery system planning and performance are being developed.

IEC TS 62933-3-1 Electrical Energy Storage (EES) systems - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specifications

The 'IET Code of Practice for Electrical Energy Storage Systems' presents the safe, effective and competent application of low voltage electrical energy storage systems and provides information on design, installation and safety considerations.

Code of Practice for Electrical Energy Storage Systems (IET, 2017)

Energy storage systems should be designed and installed in line with BS EN 61427-2:2015 'Secondary cells and batteries for renewable energy storage. General requirements and methods of test. On-grid applications.'

BS EN 61427-2:2015 Secondary cells and batteries for renewable energy storage. General requirements and methods of test. On-grid applications (BSI, 2015)

All power conditioning equipment must comply with BS EN 50160 'Voltage characteristics of electricity supplied by public electricity networks.' In addition, consideration should be given to the general safety requirements of the installation as detailed within the BS EN 50272 series.

[54] http://www.energynetworks.org/electricity/engineering/energy-storage/energy-storage-overview.html

Short circuit currents on batteries can be large, it is therefore important to consider the risks associated with arc flashes.

European Council Directive 89/391/EEC (EU Workplace Health and Safety Directive)

A battery installation will need to comply with standards specific to its battery type (such as lead acid, lithium ion, flow batteries etc.), as well as compliance with electrical installation standards

BS 7671:2008+A3:2015 Requirements for Electrical Installations. IET Wiring Regulations (IET/BSI, 2015)

Batteries present chemical hazards (due to the incorporation of corrosive, caustic or toxic chemicals) and charging hazards (due to potential gas generation and/or thermal considerations). Workplaces that have energy storage may need to be compliant with health and safety regulations referring to dangerous substances.

The Dangerous Substances (Notification and Marking of Sites) Regulations 1990 and The Dangerous Substances and Explosive Atmospheres Regulations 2002.

Lithium-Ion Batteries are classified as dangerous goods in European transport law. The shipping of lithium batteries is essentially covered by four pieces of UN legislation (UN3480, UN3481, UN3090 and UN3091) which require secure packaging to eliminate movement (within the packaging) during transit and ensure that batteries cannot come into contact with each other or a conductive surface[55].

UN 3090, Lithium metal batteries (shipped by themselves)

UN 3480, Lithium ion batteries (shipped by themselves) or, if inside a piece of equipment or packed separately with a piece of equipment as:

UN 3091, Lithium metal batteries contained in equipment; or

UN 3091, Lithium metal batteries packed with equipment; and

UN 3481, Lithium ion batteries contained in equipment; or

UN 3481, Lithium ion batteries packed with equipment.

Few if any international standards exist governing system design, battery enclosure and ventilation and maintenance testing.

## Energy conversion

When it comes to RES the overall policy for the production and promotion of energy is regulated by 2018/2001/EC which requires the EU to fulfil at least 32% of its total energy needs with renewables by 2030 with a clause for a possible upwards revision by 2023. The package includes a robust governance system for energy union, through which each Member State is required to draft integrated 10 year national energy and climate plans for 2021 to 2030[56].

[55] https://www.iata.org/whatwedo/cargo/dgr/Documents/lithium-battery-guidance-document-2017-en.pdf

[56] https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive/overview

The quality of electrical energy is regulated by the following international standards:

- EN-50160-1994 – Voltage characteristics of electricity supplied in public distribution systems
- IEC 61000-4 – Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques
- IEEE 519-1992 – Recommended practices and requirements for harmonic control in electrical power systems
- IEEE 1159 – Recommended practice for monitoring electric power quality
- IEEE 1547 – Standard for interconnecting disturbed resources with electric power systems
- IEC 62257 – Recommendations for small renewable energy and hybrid systems for rural electrification
- IEC/PAS 62111 – Specifications for the use of renewable energies in rural decentralized electrification

The following organisations are producing standards and recommendations in the electrical energy domain:

- IEEE – Institute of Electrical and Electronics Engineers – Produces standards and recommendations which covers the most aspects of utilisation of electrical energy
- IEC – International Electrotechnical Commission – Association responsible with the elaborations of International Standards which covers all the domains of electrotechnical industry
- SEMI – Semiconductor Equipment and Materials Internat – Association which represents the semiconductor industry

Wind Turbines

For a long time, there have been no requirements in many countries for independent verification of the performance, durability and reliability of wind turbine products. It has been identified that, as technologies develop, standards have not always kept up with the pace of development and variations in product design. For example, at present standards are being developed for medium-sized wind turbines, which to date have used the same standards as those employed for large-scale wind turbines. However, this is either restrictive or not appropriate for the medium-scale wind market.

The European standard EN 50308:2004 "Wind turbines: protective measures – Requirements of design, operation and maintenance" is currently being updated and it is expected that this standard will ensure that occupational safety and health is considered from the start of the turbine's lifecycle[57]

The following standards and recommendation apply for wind turbines:

- IEC 60050-415 – International Electrotechnical Vocabulary – part 415: Wind turbine generator systems
- IEC 61400 – Wind turbine generator Systems
- ANSI/AGMA/AWEA 6006-A03 –Design and Specification of Gearboxes for Wind turbines
- IEC 60076-16 – Power transformers – Part 16: Transformers for wind turbine applications

[57] https://osha.europa.eu/en/tools-and-publications/occupational-safety-and-health-in-the-wind-energy-sector

## Solar energy

The following standards and recommendations apply for PV:

- IEC 61836 – Solar Photovoltaic systems – Terms and symbol
- IEC 61724 – Photovoltaic system performance monitoring. Guidelines for measurement, data exchange and analysis
- IEC 60904 – Photovoltaic devices
- IEC 61215 – Terrestrial Photovoltaic modules
- IEC 62109 – Safety of power converters for use in photovoltaic power systems
- IEC 62093 – Power conversion equipment for photovoltaic systems
- IEC 62108 – Concentrator photovoltaic modules and assemblies – Design qualification and type approval
- IEC 62446 – Photovoltaic systems – Requirements for testing, documentation and maintenance
- IEC 62548 – Photovoltaic arrays – Design requirements
- IEC 62759 – Photovoltaic modules – Transportation testing
- IEC 62787 – Concentrator photovoltaic solar cells and cell-on-carrier assemblies – Reliability qualifications
- IEC 62788 – Measurement procedures for materials used in photovoltaic modules
- IEC 62790 – Junction boxes for photovoltaic modules - Safety requirements and tests

## Cogeneration

The relevant EU legislation and policy in cogeneration is presented as it follows

- Directive 2004/8/EC on the promotion of cogeneration based on useful heat demand in the internal energy market and amending Directive 92/42/EEC - The Directive says that Member States are to incentivize CHP over alternative generation of heat and electricity by conventional means. High efficiency CHP is defined by energy savings of more than 10 % when compared to the separate production of heat and electricity.
- Decision 2007/74/EC of 21 December 2006, establishing harmonized efficiency reference values for separate production of electricity and heat in application of Directive 2004/8/EC of the European Parliament and of the Council - The Cogeneration Directive was updated by this Commission Decision, Article 4 of which included the requirement for the Commission to establish harmonized efficiency reference values for separate production of electricity and heat for the purpose of determining the efficiency of cogeneration in accordance with Annex III of the Directive.
- Commission Decision of 19 November 2008 (2008/952/EC) establishing detailed guidelines for the implementation and application of Annex II to Directive 2004/8/EC - This Commission Decision (2008/952/EC), dated 19 November 2008 provides the detailed guidelines for the implementation of Annex II of the Cogeneration Directive. Annex II outlines the calculation of electricity from cogeneration. Until this Decision there had been no detailed guidelines for the implementation and application of this Annex.
- The Energy Performance of Buildings Directive (EPBD) 2010/31/EU - This Directive26 is a recast of Directive 2002/91/EC and is concerned with promoting energy efficiency in buildings across Europe using cost effective measures, whilst at the same time harmonizing standards across Europe to those of the more ambitious Member States. The original Directive has been

recast for the purposes of clarity in light of previous amendments and further substantive amendments to be made.

As for the standards, ISO 26382:2010 describes the technical declarations for a cogeneration system that simultaneously supplies electric power and heating and/or cooling, for planning, evaluation and procurement.

It applies to the identification of investigation items for project evaluation, cogeneration system evaluation, and primary information works for cogeneration system procurement.

It also specifies necessary check items in cogeneration system planning, provides a procedure to obtain the satisfactory configuration of the cogeneration system for each project, and includes a detailed process diagram of the key development steps.

## Electric Vehicle charging

There are no special rules related to EV charging stations installation, access and maintenance. The standards applied are the ones that are also relevant for other low voltage electrical installations and enclosures.

The main standard related to charging stations is IEC61851 *Electric vehicle conductive charging system* with the following important parts:

- Part 1 (2017): General requirements, https://webstore.iec.ch/publication/33644
- Part 21-1 (2017): Electric vehicle on-board charger EMC requirements for conductive connection to an AC/DC supply, https://webstore.iec.ch/publication/32045
- Part 21-2 (2018): Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems, https://webstore.iec.ch/publication/31282
- Part 22 (2001): AC electric vehicle charging station, https://webstore.iec.ch/publication/6031
  The standard was withdrawn and all requirements have been moved to standard IEC 61851, Part 1

The physical connection between the charging station and the EV is regulated by standard IEC 62196 *Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles* with the following parts:

- Part 1 (2003): Charging of electric vehicles up to 250 A a.c. and 400 A d.c.
  https://webstore.iec.ch/publication/20348
  The standard was withdrawn and later replaced with the new version. The content was changed and development of new version was coordinated among parts 1, 2 and 3. The newest applicable document is IEC 62196-1:2014
- Part 1 (2011): General requirements
  https://webstore.iec.ch/publication/20349
  The standard was withdrawn and later replaced with the new version. The content was changed and development of new version was coordinated among parts 1, 2 and 3. The newest applicable document is IEC 62196-1:2014

- Part 1 (2014): General requirements
  https://webstore.iec.ch/publication/6582
- Part 2 (2016): Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories
  https://webstore.iec.ch/publication/24204
- Part 3 (2014): Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers
  https://webstore.iec.ch/publication/6584

The charging stations shall comply with standards applicable to low voltage installations and control gear assemblies:

- IEC 60364-1:2005, Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions
  https://webstore.iec.ch/publication/1865
- IEC 60364-4-41:2005, Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock
  https://webstore.iec.ch/publication/1867
- IEC 60364-4-44:2007, Low-voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances
  https://webstore.iec.ch/publication/1873
- IEC 60364-7-722:2018, Low-voltage electrical installations - Part 7-722: Requirements for special installations or locations - Supplies for electric vehicles
  https://webstore.iec.ch/publication/29958
- IEC 60664-1:2007, Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
  https://webstore.iec.ch/publication/2796
- IEC 61439-1:2011, Low voltage switchgear and controlgear assemblies - Part 1: General rules
  https://webstore.iec.ch/publication/5457
- IEC 61439-2:2011, Low voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies
  https://webstore.iec.ch/publication/5458
- IEC 61439-3:2012, Low voltage switchgear and controlgear assemblies – Part 3: Distribution boards intended to be operated by ordinary persons (DBO)
  https://webstore.iec.ch/publication/5459
- IEC 61439-5:2014, Low voltage switchgear and controlgear assemblies – Part 5: Assemblies for power distribution in public networks
  https://webstore.iec.ch/publication/5462
- IEC 61439-7:2018, Low voltage switchgear and controlgear assemblies - Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicle charging stations
  https://webstore.iec.ch/publication/29556

The ingress protection and protection against external mechanical impact are regulated by:

- IEC 62262:2002, Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
  https://webstore.iec.ch/publication/6673
- IEC 60529:2013, Degrees of protection provided by enclosures (IP code)

https://webstore.iec.ch/publication/2446

Risks with charging of electric cars can be divided in various categories, presented below.

Electrical safety

The charger for electric vehicles is a pluggable device, like any household appliance. Because the field of electric vehicles charging and involved technologies are relatively new, there are some specifics that need to be taken into consideration. Regarding the electric safety there are numerous standards written on international and national levels. The electrical safety is covered in the main standard for EV charging (IEC 61851)[58].

Several protection mechanisms need to be implemented inside of electrical charger or inside the main power supply cabinet. The protection against electric shock need to be provided using the appropriate residual current device. In addition, over current protection needs to be implemented and overall design of the charger must present a safe and reliable charging solution.

All chargers that are compliant to international standards and national regulations are safe to operate and do not represent any significant risk in electrical safety.

Another aspect is the home charging via ordinary household sockets. The new analysis of the data from the Department for Transport and Zap-Map has revealed the growth rate of licensed plug-in vehicles to be almost six times faster over the last five years than that of public charging point locations in the UK. Plug-in vehicle registrations have increased from 25,983 in 2014 to 186,386 in 2018 while charging locations increased from 3,251 to 6,669.

The analysis revealed that a shocking 74 per cent believe that a lack of public charging points near their home has led them to use domestic multi-socket extension leads, not suitable for outdoor use, to charge from the mains in their home. This is despite nine in 10 being fully aware that they are dangerous to use outside, but necessity has meant they don't have another choice[59].

The usage of household sockets represents a safety risks as there is no overload protection and the charging process could easily overload the existent installation conductors. There is a risk of electric shock to human beings and livestock and a risk of fire. Normal installations are usually not adequate to enable safe charging without rework of electrical wiring.

Presumably, when the density of charging infrastructure will be adequate, less users of electric cars will be using household sockets for charging. In addition, as the awareness grows, the less and less people will be charging via household sockets.

[58] https://webstore.iec.ch/publication/33644

[59] https://www.theguardian.com/technology/2019/may/30/electric-vehicle-drivers-at-risk-by-charging-from-home-mains-supply

Fire safety

The chargers are operating with an RCD device, which is designed to protect against the risks of electrocution and in addition offers protection against fire caused by earth faults. RCD is a sensitive safety device that switches off electricity automatically if there is a fault. Like with electrical safety, the use of household sockets, multi-socket extensions and daisy chaining of extensions represent additional safety risk. Daisy-chaining is advised against in all circumstances due to the heightened risk of electric shock and fire.

Environmental safety

The RoHS directive restricts use of hazardous materials in the manufacture of various types of electronic and electrical equipment. The substances banned under RoHS are lead (Pb), mercury (Hg), cadmium (Cd), hexavalent chromium (CrVI), polybrominated biphenyls (PBB), polybrominated diphenyl ethers (PBDE), and four different phthalates (DEHP, BBP, BBP, DIBP). The restricted materials are hazardous to the environment and pollute landfills and are dangerous in terms of occupational exposure during manufacturing and recycling[60].

Another example of use of environmentally friendly materials in our products is compliance to REACH, which is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals. REACH regulation also promotes alternative methods for the hazard assessment of substances in order to reduce the number of tests on animals. Packaging of our products is environmentally friendly and materials degradable[61].

The European Commission established WEEE directive which is abbreviation for waste electrical and electronic equipment. The objective of the directive is to promote recycling, minimise waste and stimulate the development of more environmentally friendly products for the future. Although beneficial to the environment the problem of this directive is that the exact implementation is made on the national level and is not common for all the EU[62].

Impact on power system

At the moment the impact on the electrical system is low, this can change in the future. The electrical grid infrastructure will have to be adapted for larger number of electric vehicle chargers and even now it is possible that the infrastructure at some point is not good enough to enable the installation of charging stations. This is of more significance with high-speed DC charging stations.

The safety factor will become more important when the V2G solutions will be used on a large scale. The V2G technology is using the batteries of the cars as a power supply. The cars will be charging while the prices of electricity are low and when they are high, the vehicles will be suppling energy to

[60] https://ec.europa.eu/environment/waste/rohs_eee/index_en.htm

[61] https://ec.europa.eu/environment/chemicals/reach/reach_en.htm

[62] https://ec.europa.eu/environment/waste/weee/index_en.htm

the grid. With the flow of energy can flow in two ways, the safety aspect is more important and the regulations for charging stations that will be able to use V2G protocols will be stricter[63].

## Cyber threats

In a fast-developing market like EV charging, cybersecurity is often underestimated by vendors that have limited knowledge of cyber threats in general, and EV charging threats; specifically, the gaps are open for exploitation by criminals.

The commercial public EV charging ecosystems face numerous potential cyber and EV charging threats like other networked systems, such as corporate networks, mobile phones or connected vehicles. DDoS attacks, ransomware, trojan viruses, OTA file updates and app vulnerabilities that can be used for the theft of personal and financial data or the theft and hijacking of goods—such as electricity or electric vehicles.

Whether performed by criminals, disgruntled employees or hackers, there are many potential soft targets for initiating cyberattacks, including[64]:

- EV charging system hardware or physical interfaces (including publicly accessible USB ports)
- EV charging system software
- Apps for locating charging stations and paying for services
- Wireless communication links
- Physical communication links

The industry is well aware of the possible implications of cyber threats. One example of legislation on this level is the Measurement and calibration law in Germany (Mess- und Eichgesetz), popularly known as "Eichrecht". The basic principle is that the user of the electric vehicle must have an option for checking the values on the receipt. The special care must be made to ensure that there is no possibility of tampering the values of consumption, where the basis for the receipt is the meter value[65].

## Improper use

The improper use can be dangerous in any case. It could happen because of lack of knowledge or mere negligence. The industry is aware of the risks involved with improper use of the chargers. For this reason, numerous means are considered and implemented in electric chargers. Some of them would be a locking of the cable that cannot be withdrawn by accident. Special charging cables with special connectors are used to provide better safety. For example, even cable management systems could be beneficial.

Cables that have been continuously dragged on the ground will show signs of chafing and wire extrusion. Standing water, cut cables (from copper thieves) and stolen units create a dangerous situation for anyone who encounters the unit and can result in electrocution. However, most of the time, the cables are de-energized.

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[63] https://www.sciencedirect.com/topics/engineering/vehicle-to-grid

[64] https://blog.guardknox.com/ev-charging-threats-cybersecurity-ev-charging-ecosystem

[65] https://www.ptb.de/cms/presseaktuelles/zeitschriften-magazine/ptb-news/ptb-news-ausgaben/archivederptb-news/ptb-news-2014-2/neues-mess-und-eichgesetz.html

Collisions, vandalism and theft can damage these devices. The industry lacks safety precautions such as periodic inspections, signage, and safety training to protect the public and electric vehicle owners who utilize them.

**Other**

Currently, there are no statutes requiring periodic inspections of electric vehicle charging stations. The definition of periodic inspections is usually left to the manufacturer to specify. Some charging devices may be privately owned, and others may be owned and operated by a city, county or municipality. With the program in its infancy, incidents or accidents have not been reported and minimal data is available. National rules can differentiate from common principles. For example, the periodic visual assessment of chargers, in different countries of EU needs to be performed once per two weeks or according to manufacturer recommendations, which could be indefinitely[66].

Insurers can play an important role in educating policyholders about the dangers of these devices and the value of regular inspections. Commercial insurers and risk managers may want to consider requiring charging station owners to maintain some type of recordkeeping for inspections and testing to keep premiums competitive and reduce the risk of litigation. Policyholders must understand they can be held liable for any incidents involving these stations.

Electric vehicle charging stations play an important role in keeping electric vehicles on the road and safety must be a priority. Regular inspection programs can help identify issues such as malfunctions, theft and vandalism, and may decrease the chances of injuries, claims and litigation[67].

## Software

The security issues of the software systems that are going to be developed in the frame of the project need to be addressed, in compliance with EU regulation.

The first regulation refers to privacy and is included in the General Data Protection Regulation (GDPR) on the protection of natural persons with regard to the processing of personal data and on the free movement of such data.

The Regulation (EU) 2016/679 includes the corrigendum published in the OJEU of 23 May 2018. Another regulation refers to cybersecurity of data collected and processed by the software. The NIS Directive is the first piece of EU-wide legislation on cybersecurity. It provides legal measures to boost the overall level of cybersecurity in the EU.

The Directive on security of network and information systems (the NIS Directive 2016/1148) includes measures for a high common level of security of network and information systems across the Union, by ensuring a culture of security across sectors which are vital for economy and society and moreover rely heavily on ICTs. These sectors include energy. Businesses in these sectors that are identified by the Member States as operators of essential services will have to take appropriate security measures and to notify serious incidents to the relevant national authority. Also key digital service providers

[66] https://webstore.iec.ch/publication/33644

[67] https://www.propertycasualty360.com/2015/07/08/shocked-the-dangers-of-electric-vehicle-charging-s/?slreturn=20190827023022

(search engines, cloud computing services and online marketplaces) will have to comply with the security and notification requirements under the new Directive.

On 13 September 2017 the Commission adopted a cybersecurity package. The Cybersecurity Act, which has now entered into force (Regulation (EU) 2019/881), lay at the core of the package. The most important change this new EU regulation brings about is the creation of a certification framework for ICT products, services and processes. The ACEME software is an ICT based platform and it could benefit from having its processes and services certified (once these certificates are obtained, they are recognized across the European Union).

The renewable energy sources, including the BIPV solution, will be integrated in the energy management software complying all the above EU and national rules and regulations.

# 7 Conclusion

The present documents had two main objectives: the first one was to introduce the framework of Responsible Research and Innovation (RRI) and how is going to be implemented along all the duration of the project. This framework implies that the stakeholders involved in the project will work together during the whole research and innovation process in order to better align both the process and its outcomes of RE-COGNITION with the values, needs and expectations of society. RE-COGNITION aims to implement this framework by anticipating positive and negative impacts that the technology may have on humans and the environment; reflecting on the purpose and goals of the project; broadening and diversifying the stakeholder group to amplify the voices that are able to influence the project; being responsive and actively modifying the technology based on stakeholder feedback and involvement. The document also presented the first activity of RRI training for consortium members conducted on July 2019.

The second objective of the document was to i) review the already-known impact of the technology that Re-Cognition will test and deploy on humans and the environment;  and ii) review the standards for Safety and Security that are already in place, with a specific focus on the EU regulations. The review reveals the multiple risks that the potentially users of Re-Cognition might face, but it also shows that there is a very well-articulated regulatory framework at the level of European institutions to face the potential negative implications of the technologies adopted in the project.

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