Task O1/A2
Comparative study of research articles based on healthy methodologies applied to housing

BIMhealthy

HOUSING AS STRATEGY FOR HEALTH PROMOTION FROM AN INTERSECTORAL AND MULTIDISCIPLINARY APPROACH

Erasmus+

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Introduction

According to the World Health Organisation and the Pan American Health Organisation, housing is the entity that facilitates the fulfilment of a set of specific functions for the individual or the family, among which the following are included: to protect from inclement weather, to ensure security and protection, to facilitate rest or provide the resources of personal and domestic hygiene and sanitation.

Healthy housing is a conception of housing as an agent of health, which implies the fact of minimising the existing risk factors from its design and construction, and later from its use and maintenance, since it is the promoter of the health of people that live in it.

The work group responsible for TASK O1/A2. Comparative study of research articles based on healthy methodologies applied to housing, after a bibliographical review of national and international studies, from recognised sources, that analyse in depth the relations of the different conditions of elements of housing with the health of its inhabitants, propose different parameters to be included in the BIMhealthy tool and in the guide of good practices and social habits for the promotion of health with regard to housing.

*This report will be updated according to the last evidence published throughout the project

1. Outline: Relation between health determinants related to housing sanitation and the proposal on where to include the parameters: BIMhealthy tool/guide

	SANITATION DESCRIPTORS in housing		**HEALTH DETERMINANTS** related to housing sanitation	**MAIN RISKS/PROBLEMS FOR HEALTH**	**THE PROPOSAL OF PARAMETERS** will be included in:
HEALTHY methodologies applied to HOUSING	**CLIMATIC ELEMENTS**		**TEMPERATURE**	**MORTALITY MORBIDITY SLEEP DISTURBANCE STRESS**	**TOOL GUIDE**
			HUMIDITY	**RESPIRATORY DISEASES**	
			WIND	**THERMAL COMFORT**	
			NATURAL LIGHTING	**SLEEP DISTURBANCE. CIRCADIAN RHYTHM VISUAL PERFORMANCE**	
	POLLUTION AND HOUSING	**AIR QUALITY**	**CHEMICAL PHYSICAL BIOLOGICAL ELECTROMAGNETICAL**	**ASTHMA ALLERGIES COPD CARDIOVASCULAR DISEASES AIRBORNE INFECTIOUS DISEASES**	**TOOL GUIDE**
		WATER	**BIOLOGICAL AND CHEMICAL AGENTS**	**TRANSMISSIBLE INFECTIOUS DISEASES GASTROINTESTINAL DISORDERS**	**TOOL GUIDE**
		ACOUSTICS	**NOISE**	**HEARING IMPAIRMENT SLEEP DISTURBANCES STRESS CARDIOVASCULAR, GASTROINTESTINAL, NERVOUS SYSTEM, IMMUNOLOGICAL, COGNITIVE AND DISTRACTION PROBLEMS**	**TOOL GUIDE**
		CHEMICAL AGENTS	**RADON**	**CANCER**	**TOOL GUIDE**
			AMIANTHUS/ASBESTOS	**CANCER ASBESTOSIS**	
			LEAD	**IT AFFECTS CALCIUM ABSORTION, NERVOUS, NEUROLOGICAL AND CARDIOVASCULAR SYSTEM TOXICITY**	
	LIVING CONDITIONS		**SECURITY**	**UNINTENTIONAL ACCIDENTS INJURIES AND FALLS**	**TOOL GUIDE**
			ACCESSIBILITY	**TRAUMATISMS PSYCHOLOGICAL HEALTH QUALITY OF LIFE MOBILITY PROBLEMS**	
			CROWDING	**INFECTIOUS DISEASES MENTAL HEALTH/STRESS**	
	SOCIOECONOMICAL ENVIRONMENT		**SOCIAL INEQUALITY**	**DEFICIT OF QUALITY OF LIFE AND WELL-BEING**	**GUIDE**

2. Outline: Health determinants related to housing sanitation and the proposal of parameters to be included in the BIMhealthy tool

	SANITATION DESCRIPTORS in housing		HEALTH DETERMINANTS related to housing sanitation	Proposal of parameters to be included in the BIMhealthy TOOL
HEALTHY methodologies applied to HOUSING	CLIMATIC ELEMENTS		TEMPERATURE	ARCHITECTURAL MEASURES: INSULATION AND MATERIALS TEMPERATURE 23- 25ºC RELATIVE HUMIDITY%: SUMMER 45-60/ WINTER 40-50 NATURAL VENTILATION WIND SPEED 0.25 m/s winter, range up to 0.50 m/summer period LEVEL OF SUNLIGHT
			HUMIDITY	
			WIND	
			NATURAL LIGHTING	
	POLLUTION AND HOUSING	AIR QUALITY	CHEMICAL PHYSICAL BIOLOGICAL ELECTROMAGNETICAL	BARRIER MECHANISMS: FLYSCREENS NATURAL VENTILATION SYSTEM OF RENEWAL OF AIR QUALITY (MECHANICAL OR NATURAL VENTILATION) HEATING AND COOLING SYSTEM ELECTROMAGNETIC EXPOSURE 0Hz-300GHz
		WATER	BIOLOGICAL AND CHEMICAL AGENTS	MICROBIOLOGICAL CHEMICAL INDICATORS
		ACOUSTICS	NOISE	NIGHTLY NOISE: 40 dB ARCHITECTURAL ELEMENTS
		CHEMICAL AGENTS	RADON	100 Bq / m3
			AMIANTHUS/ASBESTOS	PROHIBITED MATERIALS ACCORDING TO THE SPANISH LEGISLATION
			LEAD	
	LIVING CONDITIONS		SECURITY	ARCHITECTURAL ADAPTATION ADAPTATIVE DEVICES HYGIENE-SECURITY/PREVENTIVE MEASURES
			ACCESSIBILITY	ARCHITECTURAL ADAPTATION (MINIMUM LEVEL REQUIRED FOR UNIVERSAL ACCESS BY LEGISLATION) ADAPTATIVE DEVICES
			CROWDING	MEASURES ACCORDING TO EUROSTAT
	SOCIOECONOMICAL ENVIRONMENT		SOCIAL INEQUALITY	NOT INCLUDED IN THE TOOL

3. Housing sanitation descriptors. Health determinants related to sanitation standards

3.1 Climatic elements. Causal factors based on evidence. Measures to be considered and proposals to be included in the BIMhealthy tool

CAUSAL FACTORS BASED ON EVIDENCE

It has been noted that the houses in which the climatic conditions and the energetic efficiency that reduces the exposure to extreme heat and cold, the exposure to mould and humidity are taken into account and that improve the quality of indoor air through a better natural ventilation and provide heating and safer and energetically more sufficient electrical appliances, can reduce significantly the transmission of infections, serious illnesses and they can help preventing numerous non transmissible infectious diseases (Seltenrich, 2015).

In this case, three environmental factors are present (climate parameters) which are crucial for our feeling of well-being and **they must be taken into account due to their relation with health inside the house**:

- Temperature
- Humidity
- Air speed
- Sunlight illumination

3.1.1 Temperature: indoor cold and heat

Epidemiological studies have shown that even small rises in atmospheric temperature, compared to the usual summer conditions for the local climate, can lead to a considerable increase in heat-related mortality (Nakai et al., 2002). Heat-related mortality risks may be greater in cities, people living in other urban or rural environ-ments, who are accustomed to predominantly lower temperatures, are also at risk (Gosling et al, 2009).

The exposure to very high or very low indoor temperatures can be harmful for health. Extremely low and high temperature have been associated with a **higher mortality rate**, especially among the vulnerable populations such as the **elderly** (Robert Wood Johnson Foundation, 2008).

Headache, fatigue, loss of work and concentration ability, irritability and cardiac alterations can be related to unfavourable thermal conditions. (García de Frutos et al, 2019).

Indoor cold

Cold indoor temperatures are often a consequence of outdoor temperature, structural deficiencies, including a lack of insulation and airtightness, and lack of heating (WHO Housing and Health Guidelines., 2018).

The inability to keep the house warm is an important housing problem in the majority of European countries, and a high level of inequality is also evident. The subgroups of population that live in relative poverty are significantly more affected, with various countries showing prevalence rates three or four times higher for the households below than for those above the poverty line. Inequalities are identified as well in the exposure to cold houses for single-parent households and, to a lesser extent, households with an adult older than 65.

Deaths from cardiovascular diseases are strictly related to the exposure to excess of extremely low indoor temperatures for long periods of time. It seems that 50-70% of the excess of deaths in winter are due to cardiovascular conditions, and 15-33% to respiratory illnesses.

Braubach (2011), estimates that, each year, 38,200 deaths in winter in 11 European countries are related to **low indoor temperatures**. This represents an excess of 12.8 deaths for each 100,000 inhabitants due to indoor cold.

Cold temperatures in winter were reported by a third of all households, thus showing a clear socio-economic gradient and its association with a decrease in the prevalence of different health problems or effects, such as bronchitis or cold and throat illnesses (Bonnefoy, 2007).

Low indoor temperature is the combined result of the energetic inefficiency of the housing (defective thermal insulation and/or inefficient or inappropriate provision of heating), social and economic condition of the housing and its inhabitants and cost of energy.

Interventions to mitigate the effects of cold have been associated with reduced respiratory symptoms and an improvement in mental health; double glazing has been associated with a lower probability of air streams and cough. Insulation as a part of energy efficiency packages improved the general condition of health, hospital visits and mental health. The insulation of the wall through a cavity, however, is associated to the increase in respiratory symptoms and a worsening of mental health (Poortinga et al., 2017). Other interventions or exposures did not have a statistically

significant effect not even if associated with other aspects of health (Barnard, Howden-Chapman, Clarke & Ludolph, 2018).

The inability to keep the house warm is an important housing problem in the majority of European countries, and a high level of inequality is also evident. Socioeconomic factors play an important role in determining whether a dwelling is sufficiently warm. Income constraints force people to live in housing that is older, more likely to be poorly built and lacking insulation (WHO Housing and Health Guidelines., 2018; Naicker et al. 2017). The subgroups of population that live in **relative poverty are significantly more affected**, with various countries showing prevalence rates three or four times higher for the households below than for those above the poverty line. Inequalities are identified as well in the exposure to cold houses for single-parent households and, to a lesser extent, households with an adult older than 65.

WHO working group on indoor environment finding that "there is no demonstrable risk to human health of healthy sedentary people living in air temperature of between 18 and 24 °C" (World Health Organization; 1987.)

Indoor temperatures of houses must be sufficiently high to protect the inhabitants from the harmful effects of cold. In temperate or colder countries, it is considered that an indoor temperature of 18ºC does not imply risks and it allows to protect the health of the general population in cold seasons. Firm Recommendation

In the climate areas where there is a cold season, an efficient and safe thermal insulation must be installed in new houses and in already existing ones. Conditional Recommendation.

The PHE review stated that heating houses at 18ºC at least in winter represents a minimum risk for the health of a sedentary person, with adequate clothing. (Barnard, Howden-Chapman, Clarke & Ludolph, 2018)

Indoor heat

In the areas exposed to high ambient temperatures, strategies must be elaborated and applied to protect the population from the excess of heat in indoor spaces. Conditional Recommendation (World Health Organization, 2018).

Extreme heat can also lead to a strong morbidity and mortality. From a mortality perspective, evidence shows that heat-related mor-tality is greater during early summer (Gosling et al, 2009) and also increases with the extent (or duration) of a heatwave (Rocklöv et al., 2011).The heat wave in Western Europe in Summer 2003 caused various deaths in France, Germany and Portugal, and

the reviews showed that many of these deaths were related to social isolation of single elderly persons who live in their own houses with nobody taking care of them. These data show that the condition of the housing, as well as the social integration within the neighbourhood is more than relevant (World Health Organization, 2018; Gustin et al., 2020)If we are in a hot environment, the fact of remaining still or standing for a long time and then quickly changing position can provoke a drop in blood pressure with dizziness due to the reduction of the blood flow that reaches the brain. Also, a mistake in body hydration and in the electrolyte levels implies gastrointestinal problems and muscle cramps (World Health Organization, 2018).

Another study analyses the influence of heat and acclimation on the quality of sleep at high ambient temperatures. Four persons were acclimated during six consecutive days, during the experiment the temperature was raised up to 44ºC (Di Nisi et al., 1989). The increasing acclimation did not show any effect on the quality of sleep; on the other hand, when one sleeps with a neutral thermal sensation, when one sleeps at a temperature of 35°C, the time of slow wave sleep increases since this is the sleep phase in which thermoregulation is more active. The sweating activity increases as well and it leads to a greater quantity of body cooling. Considering all these results, it seems reasonable to conclude that an **inadequate ambient temperature of the bedroom** affects the **quality of sleep** (Urlaub, Grün, Foldbjerg & Sedlbauer 2015).

The ambient temperature above the neutral temperature seems to affect the quality of low wave sleep; the REM sleep and the total time of sleep are reduced (Urlaub, Grün, Foldbjerg & Sedlbauer 2015).

There are two studies in which **stress** was induced through cold. In Sewitch et al., 1986; women slept naked and uncovered at an ambient temperature between 26.7°C and 28.3°C. The results showed only that the sleep patterns changed under mild stress, e.g. low wave sleep increased, as well as latency for the first REM phase, which are not the indicators of a deterioration of the quality of sleep under these cold circumstances. Another study, in which a stress caused by a more severe cold (21°C) was induced, with four man who slept naked and uncovered, showed that cold increases wakefulness (Palca et al., 1986).

A study (Haskell et al., 1981a, b) analysed the influence of cold and warm temperature in the stages of sleep. It has been demonstrated that the latency at the beginning of sleep was shorter in warmer conditions and the biggest sleep interruptions happened in the coolest condition. Warm conditions

reduced the duration of low wave sleep (in this specific case of 15% for an increase of 5°C) and especially interrupted the REM sleep.

Studies that analyse the quality of sleep a little beyond thermoneutrality in a room with high temperature (e.g. Lan et al., 2014, Libert et al. 1988, Okamoto-Mizuno et al., 2004) showed that a slightly elevated ambient temperature reduces the quality of sleep with regard to shorter periods of low wave sleep, a reduction of the stages of REM sleep and shorter total time of sleep.

Some studies do not only compare temperature, but also humidity, and they investigate the influence of the conditions of heat and humidity on the quality of sleep (e.g. Okamoto-Mizuno et al., 1999, Tsuzuki et al., 2004). Humidity increases the thermal load in comparison with a hot drying.

This condition is due to the limited possibility of sweating. Therefore, these studies showed, as a consequence, that the conditions of heat and humidity increased the temperature of skin (measure for thermal load) and the wakefulness and reduction of low wave sleep and REM stages Okamoto-Mizuno, 2012).

It has been noted that the houses in which the climatic conditions and the energetic efficiency that reduces the exposure to extreme heat and cold and the exposure to mould and humidity are taken into account and that improve the quality of indoor air through a better natural ventilation and provide heating and safer and energetically more sufficient electrical appliances, can reduce significantly the transmission of infections, serious illnesses and they can help preventing numerous non transmissible infectious diseases (Levasseur et al., 2017).

For the ease of the fabrication of sensors (incorporated in thermostats), the type of temperature that is generally measured is the dry temperature of air, but this is an incomplete value because it considers the loss of body heat through convection, but not through radiation. The thermal concept that is more similar to thermal sensation is the operating temperature, which includes the average radiant temperature of walls and enclosures that surround the person, since they affect decisively the thermal balance or well-being (Koop & Tadi, 2019).

With regard to the **means to keep us warm**, low consumption gas and biomass stoves in developing countries can help to avoid more than 1 million deaths caused by chronic obstructive pulmonary disease (COPD), mainly among poor women exposed to air pollution due to the emissions of the stove. The cleanest stoves can also help to avoid almost 1 million deaths annually among

children under 5 years of age due to pneumonia caused by exposure to indoor smoke (World Health Organization, 2011).

The heating of the house with energetic efficiency can also generate health and equality benefits. Solar passive combi-house and heating systems of hot water, biomass pellet stoves and heat pumps have been used in different middle-income environments to increase the level of indoor thermal comfort and reduce respiratory diseases (World Health Organization, 2011).

The efficient heating of energy can also help to reduce the risks of burns and injuries. The passive solar heating of hot water can help to improve the kitchen's hygiene (World Health Organization, 2011).

Air conditioning can strengthen the inequalities in health by exacerbating the urban noise and heat, which negatively affects other's health, particularly of those who cannot afford an air conditioner. The usage of air conditioning systems has shown that it has had a major impact on the diurnal load profile of summertime electricity demand and is associated with an increased risk of major power outages (Ostro et al., 2010)

Furthermore, air conditioning contributes to climate change due to the high levels of energy consumption and to the use of powerful greenhouse gases as refrigerants (World Health Organization, 2011).

Replacing kerosene lighting with solar lanterns can potentially reduce the risk of eye injuries, illnesses, as well as the exposure to indoor air pollution in poor houses in developing countries. Access to direct current appliances (direct current) (e.g. refrigeration, telephones, and computers) that can be powered directly through photovoltaic solar panels can improve equality in health and it can help reducing climate change (World Health Organization, 2011).

The hot roofs and the cold walls cause unease due to asymmetry. Special care must be taken with the close glazed surfaces, because in them it is complicated to check these values and, therefore, it is not advisable to stay in areas close to the building envelope (García de Frutos et al., 2019).

A cross-sectional study from the United Kingdom investigated the effects of different types of insulation on a range of health outcomes (Poortinga et al., 2017). The study identified positive effects of loft and external wall insulation on respiratory, mental and general health; but found a negative impact on these outcomes with cavity wall insulation.

Current buildings achieve thermal stability thanks to the high levels of insulation required in envelopes, the thermal characteristics of the gaps that in some cases will act as well as energy sensors and the thermal mass of the materials, which buffers the external thermal wave, thus avoiding extreme indoor temperatures, even without air conditioning (García de Frutos et al., 2019).

Other strategies, such as the orientation of the gaps, the positioning of shading devices and windbreaks, night ventilation, as well as automatized management, allow to reach levels of thermal well-being unknown until now (García de Frutos et al., 2019).

The ability to modify the hygrothermal conditions through natural ventilation converts the controlled opening of gaps into a fundamental tool to fight against overheating in summer. The shadowing of gaps and the existence of patios can help in this task. In spite of the improvements of domotic management, the users and their habits are still a key element to use air as an allied and obtain well-being (García de Frutos et al., 2019).

Measures to be considered and proposals to be included in the BIMhealthy tool

Related to indoor temperature (World Health Organization, 2012):

- To ensure an efficient insulation to reduce energy consumption and the related costs.
- To meet the standards of energy and energy costs.
- To consider the availability of low cost sources of energy such as wood, waste agricultural biomass, wind energy and geothermal sources, depending on the local situation and opportunities.
- To provide measures and information from a health perspective to avoid an extreme approach in energy savings that leads to a reduced air exchange and to a deterioration of indoor air quality: a good balance is required between ventilation and insulation.
- Operating temperature: 23-25ºC.
- There should not be a thermal gradient between head and feet higher than 3ºC, especially if the head is hotter.
- The temperature of the soil should be around 19 °C and 29 °C

3.1.2 Humidity

Humidity affects the evaporative cooling mechanisms of our physiology. That is, if the humidity is too high and the air is saturated, our body has a reduced ability to cool itself through sweat.

The high indoor values favour the proliferation of micro-organisms, they increase the possibility of condensation in walls and roofs and they can generate more pain in persons with rheumatic diseases, especially in conditions of low temperatures.

Aspergillosis, asthma, asthmatic bronchitis or chronic bronchitis are some of the health problems linked to high humidity (Hänninen, 2011).

Low values of humidity, apart from producing mucous dryness, are especially critical in case of static electricity, and it is recommended that its value, in this cases, should not fall below 50% to minimise some of the effects of the sick building syndrome. Furthermore, together with low temperatures, they facilitate the propagation of viruses. Humidity by capillarity, installations breakage and condensations can affect our health, which makes a good maintenance of the building necessary (Gupta, Khare & Goyal, 2007).

It is important to have a balanced and integrated analysis of the impact of indoor air humidity on associated health effects as opposed to the well-known problems associated with moisture-damaged buildings (World Health Organization, 2009). As pointed out the relationship between health, indoor air humidity and pollution is complex and remains a challenge (Derbywr al, 2016). These topics are important for public health services, correlating air quality with sensory irritation in eyes and airways, work performance, infection by virus, sleep quality, and the voice (Wolkoff P., 2018).

Humidity is associated with a wide range of adverse effects on health; the most common ones are related to the deterioration of the respiratory system (Mudarri and Fisk, 2007), including a higher prevalence of respiratory symptoms, a greater risk of asthma, wheezy cough (Pirastu et al., 2009), bronchitis, common cold and rhinitis (Pirhonen et al., 1996). Some studies showed a clear relation between humidity and mould and the objective measures of lung function. (World Health Organization, 2012).

Persons have 40% more probabilities of suffering from asthma when they live in a humid and mouldy house and today, 2.2 million Europeans suffer from asthma as a result of their living conditions. Asthma is not the only risk for health: allergies, disabilities and premature deaths are

also related to life in humid buildings (VELUX, 2017).

Children respiratory health is particularly damaged by living in a humid and mouldy house (Tischer et al., 2011), (World Health Organisation, 2012). More precisely, it has been estimated that 0.07 deaths related to asthma and 50 DALY (Disability Adjusted Life Years) related to asthma for 100,000 children per year are associated with the exposure to humidity in houses, and that 0.06 deaths related to asthma and 40 DALY (Disability Adjusted Life Years) related to asthma for 100,000 children per year are associated to the exposure to mould. Throat and eyes irritations, allergies, rhino conjunctivitis and eczema have also been observed (World Health Organization, 2012).

Crowded housing increases the risk of exposure to infectious diseases, and the insufficiency of water supply and sanitation services affects the innocuousness of food and personal hygiene and, therefore, it facilitates the fact of contracting transmissible diseases. (World Health Organization, 2018).

Measures to be considered and proposals to be included in the BIMhealthy tool

To make a design that amplifies natural ventilation and that can increase the exchanges of fresh air and, therefore, the quality of indoor air.
The values of relative humidity recommended in summer are between 45% and 60% and, in winter, between 40% and 50% (World Health Organization, 2011).

3.1.3 Wind

The thermal concept that is more similar to thermal sensation is operating temperature, which includes the average radiant temperature of walls and enclosures that surround the person, since they affect decisively their thermal balance or well-being. Therefore, if the speed of air is low (<0.2 m/s) and there is a small difference between the temperature of walls and roofs and the temperature of air (+- 4 °C), heat is equally eliminated by convection and radiation. But, if we get closer to a wall, although we do not touch it, we will be influenced by its temperature (Garcia de Frutos, D et al. 2019).

Air is considered as a potential enemy for air conditioning. The speed of air is limited to values inside buildings lower than 0.25 m/s in winter. However, during the summer period, this range is increased up to 0.50 m/s (Garcia de Frutos, D et al. 2019).

For this reason, the speed of air is limited to values inside the buildings lower than 0.25 m/s in winter. However, during the summer period, this range is increased up to 0.50 m/s. These values are considered for the realisation of sedentary jobs, and other norms establish values lower than 0.20 m/s for measuring the installations (Garcia de Frutos, D et al. 2019).

Measures to be considered and proposals to be included in the BIMhealthy tool

To limit the speed of air inside buildings to numbers lower than 0.25 m/s in winter, having a range of up to 0.50 m/s during the summer period.

Values lower than 0.20 m/s for measuring the installations.

3.1.4 Natural light

The access of natural light in buildings according to the needs of the occupant benefits the life cycles and the circadian rhythm (periods of sleep and wakefulness) and it helps to improve the visual contrast of objects (Garcia de Frutos, D et al. 2019).

Measures to be considered and proposals to be included in the BIMhealthy tool

The new technologies on façades help to boost and control the access of natural light.

3.2 Pollution and housing. Causal factors based on evidence. Measures to be considered and proposals to be included in the BIMhealthy tool

CAUSAL FACTORS BASED ON EVIDENCE

Indoor pollution represents a risk for the population, especially because of its effects on health, a situation accentuated by the continued presence of individuals indoor between 80%-90% of time and the **poor ventilation in houses**. The **consequences of pollutants** on health **are variable** and they largely depend on: type of pollutant, concentration, time of exposure and reactions with other pollutants to form more toxic substances. More precisely, the **pollution at home is any emission of substance and/or compound inside houses that may affect the health of their inhabitants.**

For the evaluation of the relation of pollutants in the house with health conditions, the following parameters have been considered:

- **Air Quality**
- **Water**
- **Noise**
- **Chemical agents: radon, lead and asbestos/amianthus**

3.2.1 Indoor air quality (IAQ)

Indoor air quality (IAQ) in buildings **is directly related to health, productivity and comfort of persons**.

Indoor pollution causes numerous non transmissible diseases, it damages respiratory and cardiovascular health and it causes irritations and allergic reactions, such as asthma. (World Health Organization, 2018)

The pollutants that are present in indoor air can be of three types and they depend on the activity developed in the environment, as well as on the location of the house and on its ventilation:

- **Chemical**: CO_2, CO, volatile organic compounds, etc.
- **Physical:** Presence of fibre, dust, temperature, noise, etc.
- **Biological:** Bacteria, viruses and fungi.

Also, solid fuels use for domestic heating is spread in more developed countries and it largely contributes to the exposure to polluted air. Currently, air pollution due to fuel combustion is the main environmental risk for health at a global level (World Health Organization, 2014).

Currently, air pollution in houses due to inefficient combustion of solid fuels for cooking and heating is the main isolated cause of the disease burden related to the environment (World Health Organization, 2014).

Metals can cause acute or chronic toxicity. (Baker et al., 2003). They can be inhaled as smoke or dust particles, they can be absorbed through skin and they can be ingested through food or water (Eriksen, 2014).

SBS (Sick Building Syndrome) is frequently associated with problems of indoor air quality; however, frequently, the contributing factors are related to a combination of possible causes, including indoor air pollution, absence of sunlight or daylight, inadequate heating or ventilation, bad acoustics and presence of asbestos. Biological contamination is a source of concern as well (Julian, 2010).

The airborne dispersion of viral diseases is facilitated by crowding and poor action of ventilation. (De Láncer, 2010).

It has been postulated that people living **in the highest levels of a building** will benefit from a better ventilation and direct sunlight and, therefore, **it is less likely for them to contract infectious respiratory diseases**. On the contrary, those who live in lower floors in the middle of dense groups of high buildings are more susceptible to TB infection due to the worse quality of air caused by pollution **at street level** and **by the lower exposure to direct sunlight** (Lai et al., 2013).

The documents that are considered as conclusive generally indicated that a **low rate of ventilation** is associated with a **greater risk of allergies**, symptoms of SBS (Sick Building Syndrome) and respiratory infections (Sundell et al., 2011).

The defective conditions of houses such as water leakages, poor ventilation, dirty rugs and pest infestations can provoke an increase in mould, dust mites and other allergens associated with bad health. Indoor allergens and humid housing conditions play an important role in the development and exacerbation of respiratory diseases, including asthma, which currently affects more than 29 million Americans and is the most common chronic disease among children (Pollack et al., 2008).

Housing can be a source of exposure to various carcinogenic air pollutants and we will talk about them further below.

The high levels indoor are also associated with and inadequate supply of fresh air. The methods to control exposure include adequate ventilation and the use of formaldehyde-free materials (or with low levels of it) (Braubach & World Health Organization, 2011).Implementation of thermal insulation also needs to consider the importance of using safe insulation materials, which are free of toxic substances (asbestos and isocyanate), and are resistant to fire and microbial growth (Jacobs and Forst, 2017)

In general, ventilation rates lower than approximately 25 l/s per person in offices were associated with a higher risk of symptoms of SBS. A study (Jaakkola & Miettinen, 1995) reported that increases higher than 25 l/s per person were associated with statistically significant increases in the rates of prevalence of certain symptoms; however, in general, the data on symptoms with ventilation rates higher than 25 l/s are too scarce to support general conclusions on the conditions of high ventilation. (Sundell et al., 2011).

The physical environment, especially the thermal conditions and the quality of indoor air, is important for a good sleep. Persons who wake up are influenced by these two parameters in many different ways, so one could suggest that the persons who sleep are also susceptible to suffering from distress due to a bad physical environment. (Urlaub et al., 2015).

Among 4.3 million people who die annually due to exposure to indoor air pollution, the majority dies due to stroke (34%), ischemic cardiopathology (26%) and chronic obstructive pulmonary disease (22%). Pneumonia and lung cancer represent 12% and 6% of deaths, respectively.

Women and young children, who spend the majority of time close to home, are especially vulnerable. More than 50% of deaths caused by pneumonia in children under the age of 5 are related to indoor air pollution of the house.

In 2016, indoor air pollution in houses was responsible for 3.8 deaths and for 7.7% of global mortality, according to the Global Health Observatory (Garcia de Frutos, D et al. 2019).

PM (particulate matter) can be present in form of fibres such as asbestos, discussed further below, and they are the ones that cause more problems for health. Glass fibres and other fibres that are currently used, if they come off and get into the air, can cause irritations to the skin, eyes, nose

and throat, and the long-term effects are still not very well known (Garcia de Frutos, D et al. 2019).

A typical example is **legionellosis**, caused by the bacteria *Legionella Pneumophilia*. If the water of the cooling towers or humidifiers is contaminated with the bacteria and penetrates the ventilation air in the form of aerosol (water droplets suspended in the air), dangerous conditions arise which can lead to the appearance of the disease. It can cause the disease with a serious clinical picture such as a typical pneumonia, with the possibility of death (Legionnaire's disease) or with acute fever (Pontiac fever) (Garcia de Frutos, D et al. 2019).

It has been repeatedly demonstrated, especially in the case of children, that there are socio-economical differences in the exposure to environmental air pollution, noise and smoke and the lack of access to green spaces in Europe (Bolte & Kohlhuber, 2005; Bolte, Tamburlini y Kohlhuber, 2010), (World Health Organization, 2012).

The evidence shows that the poorer the population, the more exposed it is to unfavourable environmental conditions. (World Health Organization, 2012).

Households with at least five members were more likely to use wood or coal for heating (81%). The households that heat up less than 10m^2 per member have more probabilities of burning wood or carbon (81%); the households that heat up more than 20m^2 per member use district heat (46%), carbon and wood (38%), electricity (8%) and gas (5%). Households that burn solid fuels represent a proportion higher than the average of persons who work in agriculture, trade and crafts. (World Health Organization, 2012).

In developing countries, around 700 people, mainly women and children of the poor rural areas, inhale harmful smoke deriving from the combustion of wood and other products. They are very exposed to severe respiratory infections, especially pneumonia. Indoor air pollution of houses affects around 2,500 million people, the majority of which are women and young girls and it has been estimated that every year it causes the death of more than 2.2 people, more than 98% of them in developing countries (De Láncer, 2010).

Another study shows that there are risks for health related to housing, such as: bad quality of indoor air. Diseases and injuries related to housing, where there is a significant evidence, including: tuberculosis and other **infectious airborne diseases**, asthma, water-borne diseases caused by the lack of clean drinking water and access to sanitation, **vector-borne diseases**, home injuries and mental health. (World Health Organization, 2011).

The term "ventilation" could be considered as both the ventilation rate, i.e. amount of outdoor air supplied to indoor spaces, and as the ventilation system, i.e., the way the air is supplied to indoor spaces – using natural or mechanical forces, or combined, with or without air-conditioning (AC) (Wargocki, 2016). For some pollutants the effectiveness of ventilation can be quite high, and for some pollutants it can be rather low. Ventilation can also bring the outdoor pollutants that are otherwise not present indoors.In studies with children, low ventilation rates were strongly associated with increased risk of having self-reported asthma and allergy symptoms (as wheezing, eczema and rhinitis) (Bornehag et al., 2001; Hägerhed-Engman et al, 2009). The risks for wheezing and rhinitis were significantly lower among infants in homes where heat recovery ventilators were installed.

The influence of a **personalised ventilation system next to the bed** that creates an area of clean air around the head seems to improve certain parameters of the **quality of sleep** in elderlies and to reduce stress and, therefore, increase the quality of sleep (Urlaub et al., 2015).

In houses, the emission of CO due to combustion systems (system for heating spaces or system for heating water) is generally related to: an inadequate evacuation of smoke and other combustion products (chimneys obstruction or chimneys with the wrong size); an inadequate ventilation of the rooms where the combustion systems are used; an inadequate care or inadequate use of combustion systems. (Bonnefoy, 2007).

Measures to be considered and proposals to be included in the BIMhealthy tool

The actions to prevent carbon monoxide poisoning include the regular maintenance of appliances that burn gas, oil and fuel from the ground, the fact of ensuring an adequate supply of air for the combustion of such appliances, by making sure that the occupants are aware of the danger of using inappropriate forms of heating such as smoke-free gas or thermal oil heaters.

The installation of detectors of carbon monoxide in houses with gas, oil or solid appliances (which is already compulsory in some countries) (Braubach & World Health Organization, 2011).

Vector-borne diseases can be reduced through designs of low energy houses that allow:

- To increase natural ventilation to reduce the risks of transmission of infections through air, including tuberculosis (TB); to limit the infestations of vectors and pests through measures such as the sealing of cracks and windows.

Ventilation reduces:

- risks of transmission of airborne infections, including tuberculosis;

- accumulation and exposure to toxic pollutants of the interior air of interior design materials, ovens (e.g. carbon monoxide) and natural radiation (radon).

- mould/humidity, which are risk factors for allergies and asthmas;

- risk of indoor air contamination of the air conditioning systems, including the accumulation of micro-organisms (e.g. legionella).

Air filters can help to reduce indoor air contamination.

Improved thermal isolation can reduce the risk of respiratory and infectious diseases related to cold, humidity, exposure to mould, as well as diseases from exposure to pests. However, a good ventilation is fundamental to grant health in energy-efficient and hermetically sealed houses.

The **most ecological construction materials** can reduce the health risks of the exposures to toxic chemical substances. The health risks caused by asbestos and leaded paint are well documented. Other dangerous materials include arsenic-treated wood, formaldehyde in insulation foams and pressed wood products.

The last report of 2011, carried out in the International Agency for Research on Cancer (IARC) did not lead to any solid conclusion regarding this contamination, which still has research niches to ensure its damage. Even so, the WHO establishes certain limits of exposure between 0 Hz and 300 GHz, summarised in the NTP 698 of the Spanish National Institute for Safety and Hygiene at Work (INSHT).

Table 1: Data quality objectives for evaluating ambient air quality

A. **Objetivos de calidad de los datos para la evaluación de la calidad del aire ambiente**

	Dióxido de azufre, dióxido de nitrógeno y óxidos de nitrógeno y monóxido de carbono	Benceno	Partículas ($PM_{10}/PM_{2,5}$) y plomo	Ozono y NO y NO_2 correspondientes
Mediciones fijas (1)				
Incertidumbre	15 %	25 %	25 %	15 %
Recogida mínima de datos	90 %	90 %	90 %	90 % en verano 75 % en invierno
Cobertura mínima temporal:				
— fondo urbano y de tráfico,	—	35 % (2)	—	—
— emplazamientos industriales	—	90 %	—	—
Mediciones indicativas				
Incertidumbre	25 %	30 %	50 %	30 %
Recogida mínima de datos	90 %	90 %	90 %	90 %
Cobertura mínima temporal	14 % (3)	14 % (4)	14 % (3)	> 10 % en verano
Incertidumbre de la modelización:				
Diaria	50 %	—	—	50 %
Medias octohorarias	50 %	—	—	50 %
Medias diarias	50 %	—	aún no definida	—
Medias anuales	30 %	50 %	50 %	—
Estimación objetiva Incertidumbre	75 %	100 %	100 %	75 %

Source: taken from the group report of architecture.

3.2.2 Water

Council Directive 98/83/EC is often referred to as the Drinking Water Directive (DWD). The DWD applies from the source to the tap, including treatment, materials and products used in contact with water used for drinking, cooking, food preparation, and other domestic purposes (***Materials coming into contact with drinking water at home, 2016).

In article 20, on the control of the consumer's tap, 11 parameters are established that are necessary to ensure that water is adequate for human consumption. These parameters are smell, taste, colour, turbidity, conductivity, pH, ammonium content, coliform bacteria, *E. coli* and free residual and/or combined residual chlorine and substances that can be present in the materials of the indoor facilities, such as copper, lead or iron (Garcia de Frutos et al., 2019).

The main threat of hygiene pests is the contamination of food and water through imported pathogens, particles of infected food or excrements (Ranson, 1991). (Bonnefoy, (2007).

Many studies have demonstrated that the interventions with potable water can substantially reduce the risk of diarrhoeal diseases (Clasen et al., 2007; Fewtrell et al., 2005). Diarrhoeal disease is one of the main causes of morbidity and mortality in less developed countries and in the less developed areas of emerging countries, especially among children. (World Health Organization, 2012).

The improved supply of water can improve the health condition by allowing a better hygiene, and possibly also by reducing the need for storage in the house and for water transportation, two factors that are related to the risk of water contamination (World Health Organization, 2012).

The characteristics of poor housing, including the lack of safe potable water, the absence of hot water for showering, the ineffective disposal of waste, the intrusion of vector-borne diseases (e.g. Insects and rats) and the inadequate storage of food have been identified as contributing to the diffusion of infectious diseases (Krieger & Higgins, 2002).

Also, the inadequate supply of water has a great impact on health, since it leads to a high prevalence of water-borne diseases. (World Health Organization, 2012).

88% of diarrhoeal diseases are due to unsafe water and to poor sanitation and hygiene, thus reducing between 6% and 21% the morbidity associated in case of a correct provision of potable water (Garcia de Frutos et al, 2019).

The improvement of the quality of water in the point of consumption through the treatment of

domestic water potentially reduces between 35% and 39% the occurrences of diarrhoea (Garcia de Frutos et al, 2019).

In the European Region of the WHO, an average of 330,000 cases of serious diseases related to water are reported every year, including campylobacteriosis, viral hepatitis A, giardiasis, Shigella (bloody diarrhoea), infection due to Enterohemorrhagic Escherichia coli, legionellosis and cholera (WHO, 2011b). (World Health Organization, 2012).

The improvements in the access to potable water and to adequate sanitation could reduce the infant mortality rate in 2.2 million per year. (World Health Organization, 2012).

Bacterial contamination of drinking water is a majorcontributor to water-borne diseases in rural areas of mostdeveloping countries where water sources are communallyshared (Nguendo-Yongsi, 2011; Delaire et al., 2017) and exposed to multiple faecal-oral trans-mission pathways in their neighbourhood boundaries (Thevenon et al., 2012; Jung et al., 2017; Gwimbi et al., 2019)

The inhabitants of the rural areas are particularly exposed to inadequate sources of potable water; they face a greater vulnerability to water-borne diseases due to the lack of access to a water distribution network or to the distance from water sources (World Health Organization, 2012).

Clouatre (2013) studied the effect of a legislation that requires that all the new or renewed residential buildings reduce the maximum configuration of their hot water heater to 49°C (120 ° F) by **installing anti-scald mixing valves**. (Bhaumik et al, 2018).

Measures to be considered and proposals to be included in the BIMhealthy tool

Table 2: Microbiological parameters and parametric values

Parámetros microbiológicos

Parámetro	Valor paramétrico (número/100 ml)
Escherichia coli (E. coli)	0
Enterococos	0

A las aguas comercializadas en botellas u otros recipientes se aplicarán los valores siguientes:

Parámetro	Valor paramétrico
Escherichia coli (E. coli)	0/250 ml
Enterococos	0/250 ml
Pseudomonas aeruginosa	0/250 ml
Recuento de colonias a 22 °C	100/ml
Recuento de colonias a 37 °C	20/ml

Source: taken from the group report of architecture

Table 3: Chemical parameters and parametric values

Parámetros químicos

Parámetro	Valor paramétrico	Unidad	Notas
Acrilamida	0,10	µg/l	Nota 1
Antimonio	5,0	µg/l	
Arsénico	10	µg/l	
Benceno	1,0	µg/l	
Benzo(a)pireno	0,010	µg/l	
Boro	1,0	mg/l	
Bromato	10	µg/l	Nota 2
Cadmio	5,0	µg/l	
Cromo	50	µg/l	Nota 3
Cobre	2,0	mg/l	Nota 3
Cianuro	50	µg/l	
1,2-dicloroetano	3,0	µg/l	
Epiclorhidrina	0,10	µg/l	Nota 1
Fluoruro	1,5	mg/l	
Plomo	10	µg/l	Notas 3 y 4
Mercurio	1,0	µg/l	
Níquel	20	µg/l	Nota 3
Nitrato	50	mg/l	Nota 5
Nitrito	0,50	mg/l	Nota 5
Plaguicidas	0,10	µg/l	Notas 6 y 7
Total plaguicidas	0,50	µg/l	Notas 6 y 8
Hidrocarburos policíclicos aromáticos	0,10	µg/l	Suma de concentraciones de compuestos especificados; nota 9
Selenio	10	µg/l	
Tetracloroeteno y tricloroeteno	10	µg/l	Suma de concentraciones de parámetros especificados
Total trihalometanos	100	µg/l	Suma de concentraciones de compuestos especificados; nota 10
Cloruro de vinilo	0,50	µg/l	Nota 1

Source: taken from the group report of architecture.

Table 4: Indicator parameters

Parámetros indicadores

Parámetro	Valor paramétrico	Unidad	Notas
Aluminio	200	µg/l	
Amonio	0,50	mg/l	
Cloruro	250	mg/l	Nota 1
Clostridium perfringens (incluidas esporas)	0	número/100 ml	Nota. 2
Color	Aceptable para los consumidores y sin cambios anómalos		
Conductividad	2 500	µS cm^{-1} a 20 °C	Nota 1
Concentración en iones hidrógeno	≥ 6,5 y ≤ 9,5	unidades pH	Notas 1 y 3
Hierro	200	µg/l	
Manganeso	50	µg/l	
Olor	Aceptable para los consumidores y sin cambios anómalos		
Oxidabilidad	5,0	mg/l O_2	Nota 4
Sulfato	250	mg/l	Nota 1
Sodio	200	mg/l	
Sabor	Aceptable para los consumidores y sin cambios anómalos		
Recuento de colonias a 22 °C	Sin cambios anómalos		
Bacterias coliformes	0	número/100 ml	Nota 5
Carbono orgánico total (COT)	Sin cambios anómalos		Nota 6
Turbidez	Aceptable para los consumidores y sin cambios anómalos		Nota 7

Source: taken from the group report of architecture

3.2.3 Acoustics

The undesired or unpleasant sound is called noise. Acoustic pollution happens mainly due to typical human activities. Road traffic is considered as the major source of external noise. According to the report *Noise in Europe*, published by the European Environment Agency, acoustic pollution is the major problem of environmental health in Europe (García de Frutos et al., 2019).

The main steps necessary to estimate the burden of disease of traffic noise include (Braubach, Jacobs & Ormandy, 2011):

- To establish relations of exposure-response between the exposure to noise and the risk of DHI by using the results of the published meta-analyses.
- To estimate the percentage of the study population that is exposed to traffic noise.
- To exceed the harmful levels -in this case 60 dB (A)- during the day (16 hours, from 7.00 am to 11.00 pm) and/or 50 dB (A) during the night (8 hours, from 11.00 pm to 7.00 am).
- To collect the health statistics for the ischemic heart disease (in cases, deaths and/or DALY) of the estimates of the global burden of disease.
- To calculate the population attributable fraction (PAF) for each group of age and level of exposure.

The guidelines of environmental noise of the WHO for the European Region give recommendations to protect human health from the exposure to environmental noise deriving from different sources, such as transport noise (road traffic, railways and planes), wind and noise of turbines and leisure time noise (WHO, 2018).

Noise was declared as an environmental pollutant by the World Health Organization at the beginning of the seventies and it was soon considered as one of the most common forms of pollution of the urban areas that affect the quality of life of the persons that live in them (García de Frutos et al., 2019).

Noise is a stress factor that produces physical and psychological results, with harmful effects on the nervous, gastrointestinal and cardiovascular system. 4.8 cases of myocardial infarction and 30.1 cases of ischemic heart disease occur per each 100,000 inhabitants. They are caused by traffic noise. There are three possible approaches to protect the inhabitants from traffic noise: the first one aims at reducing the sources of noise of vehicles; the second one aims at **modifying the housing** (better sound, insulation and attenuation) and the third one aims at reducing the possibility of noise reaching the inhabitants (Braubach, Jacobs & Ormandy, 2011).

Noise has effects on hearing, but also on blood pressure and cardiovascular diseases. And, of course, since it interferes with sleeping, it provokes neurological and psychological alterations (García de Frutos et al., 2019).

It is considered that noise is a non-specific stress factor that contains both physical and psychological factors (Braubach, Jacobs & Ormandy, 2011).

Stress caused by persistent noise increases the risk of diseases related to stress, including immunosuppressive, gastrointestinal and cardiovascular disorders (Braubach, Jacobs & Ormandy, 2011). Noise alters the ability of a living organism to effectively face the stimuli that threat homeostasis and it is partly determined by its ability to start a cascade of neurochemical and behavioural responses. This usually transitory response improves the alertness at a cognitive level, it suppresses non-essential behaviours (such as eating), it increases the immune response (through cell translocation) and it triggers an activation of the hypothalamic-pituitary-adrenal (HPA) axis (Braubach, Jacobs & Ormandy, 2011).

Noise is related to the presence of cardiovascular diseases such as hypertension, ischemic heart disease (including myocardial infarction). The risk increases when the levels of average noise are higher than 60 dB (A) during the day, which corresponds to levels of noise during the night of approximately 50 dB (A) (Braubach, Jacobs & Ormandy, 2011).

Environmental noise damages health if the level of noise during the day (16 hours) is higher, in the façade of the house, than 65dB (European Environment Agency, 2001) (Braubach, Jacobs & Ormandy, 2011).

Excessive stimulation provokes distraction and overloading, which interfere with the cognitive processes that require effort or concentration. Over-stimulation is an obstacle for attention and it interrupts the planned ongoing patterns of action. The levels of stimulation are influenced by properties of indoor settings such as intensity, complexity and the innovation of the characteristics of the stimulus. Loud noise, bright light or strong odours and bright and unusual colours, especially in the red end of the spectrum, seem to increase stimulation (Evans & McCoy, 1998).

Aspects to consider for the quantification of noise in the house

Due to the wide range of values in the pressure magnitude, the logarithmic scale is used by using the concept of sound pressure level (SPL), whose unit of measurement is the decibel (dB). In this way, the audible range is transformed in 0 dB and 140 dB, being the latter the pain threshold. Given its logarithmic character, when one adds the sound pressure level of two noise sources, it is necessary to use a procedure of logarithmic sum. For example, the sum of the two sources that emit at 50 dB each is not equal to 100 dB, but rather to 53 dB (García de Frutos et al., 2019).

The exposure indicators based on energy (Leq) are adequate and sufficient for the evaluation of the relation between the long-term exposure to community noise and chronic diseases.

To quantify airborne sound insulation between two enclosures, the parameter difference of levels D is used, which is the difference between the sound pressure level produced in the issuing enclosure and the sound pressure level produced in the enclosure (García de Frutos et al., 2019).

To obtain the acoustic insulation of a construction element, such as a wall or a façade, it is used a parameter index of acoustic reduction of a construction element R. This parameter, also expressed in decibels A, cannot be measured *in situ*, it can only be obtained in a laboratory. In both cases, the higher the values of D or R, the greater the airborne sound isolation between the enclosures or the partition (García de Frutos et al., 2019).

The impact sound is transmitted in a structural way and it is quantified in impact sound pressure level, L, in decibels, which is the noise pressure level in the receiving enclosure. In this case, the lower the value obtained, the lower the received pressure level in the receiver and, therefore, the greater the insulation between enclosures. The materials and systems used to improve acoustic insulation from airborne noise and impact noise of the construction systems are quantified with the symbol ΔR and ΔL, respectively. The acquired value depends on the mass of the basic element (García de Frutos et al., 2019).

Acoustic conditioning inside enclosures can be quantified with the reverberation time, T, in seconds, which is the time necessary for the sound pressure level to decrease by 60 dB after the cease of the source. To reduce the reverberation time in an enclosure, the coefficient of sound absorption of

the lining materials of the room must be increased, or their areas must be increased (García de Frutos et al., 2019).

The night noise guidelines of WHO for Europe are specific recommendations for the levels of exposure to noise during night, issued by the Regional Office of the WHO for Europe in 2009. The guidelines provide advice based on evidence to the Member States for the development of future legislation and political action in the area of evaluation and control of exposure to night noise. The values of reference are (WHO, 2018).

Measures to be considered and proposals to be included in the BIMhealthy tool

- **The value of reference of night noise: 40 dB Lnight**. Furthermore, it was recommended a value of Lnight of 55 dB as TI for the countries that could not follow the short-term guidelines due to various reasons or where the policy makers decided to adopt a gradual approach (WHO, 2018).
- Construction elements of acoustic insulation:

  Presence of self-supporting wall made of gypsum plasterboard with mineral wool in the cavity.
  Suspended ceiling or floating floor with noise absorbing materials that improve the airborne sound insulation of the partition. When it comes to selecting these materials, the manufacturer must provide the parameter ΔR.

  To improve sound insulation from the outside, it is essential to use suitable windows.

3.2.4 Chemical agents: radon, amianthus/asbestos, lead

Over 850 chemicals have been identified as producers of neurobehavioural disorders. Depression is one of the most common symptoms associated with exposure to neurotoxins (Eriksen, 2014).

Building industry rating systems, product certifications, design firms, and owners have acces to the developed and published chemical avoidance lists (Yang and Tepfer,, 2018). The following chemical avoidance lists are publicly available and frequently referenced in the building industry. A more comprehensive set of lists are available within the Pharos database (Pharos. Healthy Building network. 2016).The divergence in chemical avoidance list methodologies and motivations results in inconsistencies among lists (Figure 1)

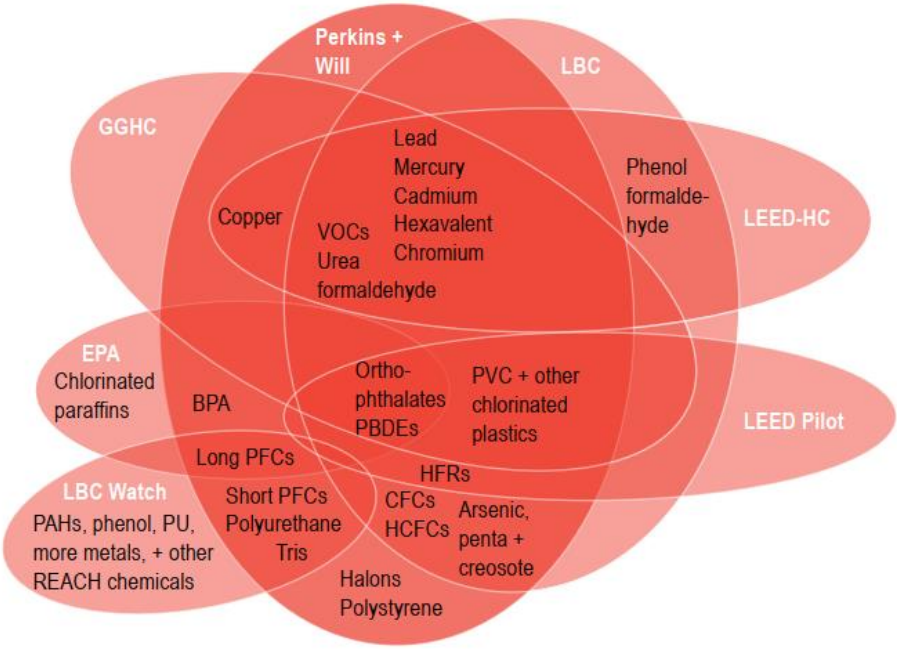

Figure 1: The overlap of specific chemicals among the following lists (clockwisestarting at top): CPA-HBN Red List in Pharos, Perkins+Will PrecautionaryList, Living Building Challenge Red List, LEEDv3 2009 for Healthcare MRc4.1 and MRc4.2: PBT Source Reduction and MRc5: Furniture and Medical Furnishings, LEEDv3 2009 for New Construction MRpc54: Avoidance of Chemicals of Concern, Living Building Challenge Watch List, EPA Chemicals of Concern - Action Plan Published list, and Green Guide for Healthcare substances targeted for reduction (Yang and Tepfer,, 2018). The commonalities among the lists depicted in previous figure include:

- addressing chemical hazards beyond indoor air pollutants

• containing some PBTs, or toxic substances like mercury, that move up the food chain and often spread from their origination point to areas with no perceived risk

• considering negative effects that occur either upstream ("supply chain" impacts) or downstream ("end-of-life" impacts) in the life cycle of the substance

• including substances that have shown negative effects at very low concentrations (e.g., cadmium and mercury) within a living body

For the evaluation of the health-related aspects of housing in terms of contamination by chemical agents, the following parameters have been taken into account due to the great influence shown:

- Radon
- Lead
- Amianthus/asbestos

Radon

Radon, a naturally occurring radioactive gas that escapes from the ground, has been associated with lung cancer. Calculations have shown that one in fifteen households have high radon levels (Pollack et al. 2008).

An evaluation on the environmental burden of disease associated with inadequate housing in the WHO European Region (2011) indicates that exposure to radon is linked to more than 3,000 deaths per year in the three countries of France, Germany and Switzerland, with mortality rates per 100,000 ranging from 2.1 (France) to 3.2 (Switzerland).

Radon is a radioactive gas of natural origin emanating from certain types of soil, although it can also be caused by some construction products or by water extracted from wells in contact with this type of soil. Outdoors, radon emissions quickly dilute to very low concentrations between 5–15 Bq/m3, therefore they are generally not a problem. However, indoors, radon concentrations are higher and can be detrimental for health. Topical, dermal and superficial contact with radioactive radon particles is not offensive, but when breathed and/or inhaled, they enter the body and settle on the cells covering the airways, where they can damage DNA and cause lung cancer.

In 2005, the WHO created the International Radon Project, aimed at identifying effective strategies to reduce the impact of this gas on health and at raising awareness among the general public and

policy makers of the consequences of prolonged exposure. Therefore, in 2013, the European Commission published the European Council Directive 2013/59 Euratom establishing the basic safety standards for protection against the dangers arising from exposure to ionising radiations. For this reason, the Spanish Ministry of Public Works has recently published the basic document DB HS-6 of the Spanish Technical Building Code (*Código Técnico de la Edificación,* CTE), with the aim of adding a new section: «*HS-6 Protección frente a la exposición al radón*» [HS-6 Protection against radon gas exposure] and the modification of Part 1 of the CTE (chapter 3, article 13, paragraph 3), which includes the new regulatory requirement that buildings have the necessary means to limit the foreseeable risk of inappropriate exposure to radon escaping from the ground in closed areas (García de Frutos et al., 2019).

Measures to be considered and proposal to be included in BIMhealthy

The WHO proposes a reference level of **100 Bq/m^3** to minimise health risks due to indoor radon exposure. (World Health Organization, 2014).

Lead

Most lead exposures occur at home, specifically in homes built before 1978 that often contain lead-based paint and lead in the plumbing systems. Paint deterioration in older homes is the main source of lead exposure for children who eat paint chips and inhale lead-contaminated dust. Between 1998 and 2000, one quarter of the nation's homes, 24 million homes, were estimated to have significant lead-based paint hazards (Robert Wood Johnson Foundation, 2008).

The amount of lead dissolved in water from plumbing facilities depends on several factors, particularly pH, temperature, water hardness and the time that it remains in the pipes (soft, acidic water is the one that best dissolves lead). In 2003 the maximum lead levels in drinking water were set and are currently 10µ/litres. This makes it necessary to replace lead facilities and some copper facilities that used lead to seal joints (García de Frutos et al., 2019).

In the early 1990s, the World Health Organization (WHO) noted that lead is a general poison that accumulates in the skeleton. Breastfed babies, children up to six years of age and pregnant women are the most vulnerable ones to its negative health effects. Lead also hinders calcium metabolism and is toxic to the nervous system, both central and peripheral, with subencephalopathic and behavioural neurological effects (García de Frutos et al., 2019).

Lead pipes have been used in drinking water facilities in buildings until the late 1970s. They were gradually replaced by iron and copper (García de Frutos et al., 2019).

Around 66% of the lead exposure burden (and its influence on mild mental retardation and cardiovascular effects) is due to home-based exposures, that includes lead-based paint and contaminated dust and soil, and it is estimated to cause about 695,000 DALYs per year. (Braubach, M., & World Health Organization, 2011)

Lead poisoning irreversibly affects brain and nervous system development, resulting in lower intelligence and reading disabilities (Robert Wood Johnson Foundation, 2008).

Lead present in the home through paints, pipes and soil causes neurological, cognitive and developmental problems in children; while in adults it causes cardiovascular and neurological problems. Other important adverse health effects that occur with higher exposures to lead include disorders such as anaemia, decreased kidney function, GI effects, decreased reproductive health, reduced height, hearing loss, encephalopathy, seizures, coma and death (Braubach, Jacobs & Ormandy, 2011).

No safe level of exposure to lead has been identified and even low levels of exposure can cause a wide range of toxic effects. Lead exposure can increase blood pressure, which is the most important risk factor for cerebrovascular disease. Based on 2015 data, lead exposure is estimated to represent 12.4% of the global burden of idiopathic intellectual disabilities, 2.5% of the global burden of DHI, 2.4% of the global burden of stroke, 4.4% of hypertensive heart disease, 0.8% of rheumatic heart disease and 1.4% of other cardiovascular diseases worldwide. Lead exposure has also been linked to chronic kidney disease in various settings. It is estimated that lead exposure caused 853,000 deaths in 2013 (WHO, 2018).

Young children are particularly vulnerable to lead because they absorb four to five times more ingested lead than adults from a specific source. In addition, the innate curiosity of children and their hand-to-mouth behaviour appropriate to their age lead them to swallow objects containing lead or covered by lead. High levels of lead attack children’s brain and central nervous system to

cause coma, seizures and even death. Exposure to even low levels of lead during childhood has been associated with attention-deficit disorder and neurodevelopmental disorders, including reduced intelligence quotient (WHO, 2018).

Finally, inorganic lead has been classified as a probable human carcinogen by both the International Agency for Cancer Research and the US Environmental Protection Agency. Neurological and behavioural problems include reduced IQ (Lanphear et al., 2005), attention deficits (Braun et al., 2006), hyperactivity, reduced organisational skills and juvenile delinquency and criminal behaviour in adulthood. Lead exposure affects the executive function and impulse control (Braubach, Jacobs & Ormandy, 2011).

Measures to be considered and proposal to be included in BIMhealthy

In 2003 the maximum lead levels in drinking water were set and are currently 10µ/litres (García de Frutos et al., 2019).

Measures for the elimination of lead (WHO, 2018):

- To eliminate the use of lead in paints worldwide.
- To eliminate the use of lead solder in food and beverage cans and water pipes.
- To eliminate the use of lead in homes, schools, school materials and children's toys.
- To eliminate the use of lead glaze for pottery intended for cooking, eating or drinking.
- To encourage the removal of pipes and fittings containing lead (as this is expensive, other measures, such as corrosion control and minimising lead dissolution in water systems should be implemented in the meantime).

Amianthus/Asbestos

Asbestos or amianthus can be found in houses with tile floor, textured roofs, roof tiles, thermal insulation, electrical insulation (around boilers, ducts, pipes, sheets and chimneys), pipe cement, glue and jointing compound. Asbestos is used as a fibrous mixture and can be inhaled and ingested (WHO; 2018).

Exposure to asbestos fibres occurs particularly in circumstances where asbestos products have degraded, such as when the house is in poor conditions or during building maintenance, renovation, demolition or destruction (as might occur in a disaster) (WHO; 2018).

The NTE-IPF/1974 standard recommended the use of asbestos mortars and the NBE-CPI-82 standard considered the option of 1.5-centimetre-thick mortar on metal mesh within its boards to protect pillars against fire. Asbestos mortar was banned in 1994 (García de Frutos et al., 2019).

The EU has proposed that asbestos be removed from all buildings by 2028. Although there is currently no census of buildings with asbestos-containing products –it is estimated that there are still some 2.6 tonnes of products with asbestos fibres installed in buildings in Spain–, the "asbestos removal" is an important professional challenge that must be carried out by specialised companies. Product with asbestos must be deposited in a hazardous waste management centre, where they are buried while awaiting the use of viable techniques for their elimination such as fusion (García de Frutos et al., 2019).

Asbestos exposure has very negative effects on health, and can lead to various diseases such as:

Fibre incrustations in the epidermis: the fibres that are detached are embedded in the skin forming skin warts.

Inhalation of fibres: the most worrying one is linked to serious progressive disabling diseases, such as asbestosis and different types of cancer, such as lung cancer (WHO, 2018).

Occupational and domestic exposure to asbestos is linked to a series of cancers, including lung cancer, laryngeal cancer, mesothelioma, ovarian cancer and stomach cancer. There is no safe level for exposure to asbestos (WHO, 2018).

The global burden of disease attributable to asbestos was estimated at 107,000 deaths and 1,523,000 DALYs in 2004. Among these, 41,000 deaths and 370,000 DALYs were due to lung cancer caused by asbestos, and 7,000 deaths and 380,000 DALYs were due to asbestosis. The 59, 000 other deaths and 773,000 DALYs were attributed to malignant mesothelioma. Approximately one in three deaths from occupational cancer is caused by asbestos. Currently, about 125 million people in the world are exposed to asbestos at the workplace. In addition, it is estimated that several thousand deaths per year can be attributed to exposure to asbestos at home (WHO, 2018).

Measures to be considered and proposals to be included in the BIMhealthy tool

Asbestos is a proven human carcinogen (Group IARC 1). It is not possible to propose a safe level for asbestos because no threshold is known to exist. Therefore, exposure should be kept as low as possible.

3.3 Conditions of habitability. Causal factors based on evidence. Measures to be considered and proposals to be included in the BIMhealthy tool.

CAUSAL FACTORS BASED ON EVIDENCE

After the bibliographic review on aspects related to habitability, three factors are considered for their relationship with health:

- **Safety at home. Non-intentional accidents and injuries**
- **Accessibility**
- **Crowding**

3.3.1 Safety at home. Non-intentional accidents and injuries

The WHO defines an accident as "an unintended event resulting in identifiable bodily harm". Today, accidents in developed countries are one of the leading causes of illness and death. Unintentional injuries (UI), often referred to as "accidents", produce bodily harm, which is characterised by the immediacy between the time of exposure to the risk factor and the injury that occurs.

The home is the place that offers the greatest safety and peace of mind to people. However, sometimes, both adults and children can have accidents at home.

Given the fact that people spend a lot of time at home, it is also there where the greatest chances of accidents of any kind arise. There is evidence that not all family members have the same chances of having an accident. There are three groups of people who have accidents most frequently (FACUA, 2010):

- Children under **5 years of age.**
- **Housewives:** Women, especially those over 45, are one of the most frequently injured groups within the household. The kitchen is one of the key settings for these accidents to occur.
- **People over 65. Falls** are the main cause of injuries for elderly, especially women. As we get older, the chances of falling are greater. 30% of those over 65 and 50% of those over 80 fall at least once a year

According to the data from the Spanish Ministry of Health, Social Services and Equality (2013), the likelihood of a body part being damaged varies depending on where the accident occurs. If we focus on the inside of the house, the following table shows the most serious place according to the place of the accident (%).

Table 5: More serious injury by place of the accident

Tabla 6.4 Lesión más grave según el lugar del accidente (%)

Lugar dónde se produjo el accidente	TOTAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
ÁREA DE TRANSPORTE	**13,2**	**16,0**	**17,0**	**5,8**	**9,2**	**18,9**	**14,9**	**18,5**	**6,6**	**12,0**	**12,1**	**7,8**	**0,0**	**2,5**	**1,8**	**0,0**	**0,0**	**12,5**	**0,0**	**4,6**	**6,0**	**8,5**	**9,6**
Acera, paso de peatones	4,7	5,7	6,5	2,3	3,2	5,8	6,2	6,9	3,3	8,0	2,8	1,1	0,0	0,4	0,2	0,0	0,0	0,0	0,0	2,3	0,0	3,4	4,8
Calzada para ciclistas	0,2	0,0	0,4	0,0	0,3	0,1	0,7	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Vía pública fuera del área urbana	0,2	2,3	0,3	0,4	0,1	0,2	0,5	0,2	0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Vía pública dentro del área urbana	6,9	8,0	8,6	2,7	4,6	11,1	6,4	9,7	3,3	4,0	7,3	4,5	0,0	1,3	1,0	0,0	0,0	12,5	0,0	2,3	3,0	3,9	4,8
Carretera sin especificar	0,3	0,0	0,4	0,4	0,1	0,5	0,2	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,6	0,0
Estación de autobuses, área ferroviaria, terminal de carga, etc.	0,4	0,0	0,5	0,0	0,2	0,5	0,5	0,6	0,0	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Muelle, vías y ctra. de acceso de vehículos al puerto	0,1	0,0	0,0	0,0	0,1	0,1	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Área de transporte, otros lugares especificados	0,2	0,0	0,2	0,0	0,1	0,3	0,2	0,3	0,0	0,0	1,6	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,0	0,0	0,0
Área de transporte, sin especificar	0,2	0,0	0,1	0,0	0,5	0,3	0,2	0,2	0,0	0,0	0,4	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,6	0,0
INTERIOR HOGAR	**54,5**	**62,0**	**56,9**	**77,2**	**65,9**	**44,9**	**43,3**	**31,5**	**66,6**	**66,0**	**37,8**	**69,4**	**100,0**	**43,6**	**92,5**	**88,3**	**40,0**	**0,0**	**0,0**	**84,0**	**60,7**	**56,5**	**52,4**
Cocina	19,3	3,4	8,3	61,2	37,4	5,0	5,0	4,5	20,0	36,0	4,8	5,7	0,0	6,8	76,7	23,5	20,0	0,0	0,0	31,8	6,1	12,9	0,0
Comedor, dormitorio	17,4	34,5	23,4	9,7	14,8	16,3	17,7	10,2	26,7	18,0	19,4	34,1	0,0	28,4	10,7	11,8	0,0	0,0	0,0	38,6	36,4	29,2	28,6
Cuarto de baño, lavabo, aseo	4,7	10,3	7,8	1,9	3,4	4,7	4,0	4,0	3,3	6,0	4,8	8,0	0,0	0,8	2,9	29,4	0,0	0,0	0,0	2,3	6,1	2,8	4,8
Escaleras interiores	3,3	4,6	5,1	1,2	1,5	4,5	4,5	5,3	3,3	0,0	0,8	2,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,8	0,0
Interior de la casa, otros lugares	2,5	2,3	3,9	0,0	2,4	3,8	3,1	1,1	3,3	2,0	0,8	5,7	50,0	1,3	0,4	5,9	0,0	0,0	0,0	0,0	0,0	2,2	0,0
Exterior de la casa (balcones, fachadas, tejados, escaleras exteriores)	4,6	6,9	6,1	1,6	3,0	7,9	5,9	4,5	6,7	0,0	4,0	5,7	50,0	2,1	1,0	0,0	0,0	0,0	0,0	4,5	0,0	2,2	19,0
Área de juegos en la zona residencial o comunidad de propietarios	0,1	0,0	0,0	0,4	0,2	0,0	0,0	0,2	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,0	0,0	0,0

1=Conmoción cerebral; 2=Contusión-magulladura; 3=Abrasión; 4=Herida abierta; 5=Fractura; 6=Luxación, dislocación; 7=distorsión-torcedura, esguince; 8=Lesión nervios; 9=Lesión de vasos sanguíneos; 10=Lesión de tendones o músculos; 11=Aplastamientos; 12=Amputación; 13=Envenenamiento o intoxicación; 14=quemadura o escaldadura; 15=Corrosión (producto químico); 16=Electrocución; 17=Radiación; 18=Congelación; 19=Asfixia; 20=Ninguna lesión diagnosticada; 21=Otro tipo de lesión diagnosticada; 22=Tipo de lesión sin especificar.

It is worth noting that most of the bodily injuries occur inside the home, especially injuries to the lower back (74.9%), the upper limbs (especially in the kitchen with 40.1%), the thorax (66.2%) and the head (60.0%).

The **kitchen**, the **dining room** and the **bedroom** are the most dangerous rooms, since the percentage of accidents registered in most body parts in these rooms is significantly higher than in the other areas of the house.

The kitchen is the room in which the highest percentage of accidents related to food preparation or intake occur: burns (76.7%), grazes (61.2%), open wounds (37.4%) and asphyxiation (31.8%).

The **outside of the house** (balconies, façades, roofs or external stairs) is the setting with the greatest propensity for contusions (6.1%) and fractures (7.9%).

The interior **stairs** also concentrate a significant percentage of injuries, especially sprains (5.3%), contusions (5.1%), fractures and dislocations (4.5% respectively).

On the other hand, according to the Spanish Ministry of Health, Social Services and Equality (2013), we find this relationship between the **number of persons**, the **size of the house** and the **accident rate**. A direct link is also observed between the **size of household** and the **age of the injured person**, in such a way that, as the average age of the injured person increases, the average size of the family decreases and vice versa.

A certain correlation is observed between the demographic concentration within the household and the size of the house, in such a way that, as the number of members in the house increases, the number of square metres of the house increases, and conversely (DADO, 2011).

Table 6: Accident rate according to age and number of people living at home (%)

Edad y número de personas en el hogar	Una	Dos	Tres	Cuatro	Más de cuatro
TOTAL	12,4	27,2	25,2	24,5	10,7
Hombres	9,7	22,5	26,7	28,6	12,4
Mujeres	14,3	30,5	24,2	21,5	9,5
Menos de 1 año	-	-	46,7	26,7	26,7
1 a 4 años	-	5,6	36,2	36,7	21,4
5 a 14 años	-	4,9	26,4	48,5	20,1
15 a 24 años	2,4	11,8	30,5	36,3	19
25 a 44 años	12,6	30,4	27,3	21,9	7,8
45 a 65 años	13,2	31,7	26,4	21,8	7,0
Más de 65 años	28,7	47,7	13,7	5,4	4,6

Fuente: D.A.D.O. 2011

Table 7: Accident rate according to number of people and size of the house (%)

Número de personas y tamaño del hogar*	Superficie de la vivienda donde se produjo el accidente				
	Menos de 50 m^2	De 50 a 70 m^2	De 71 a 100 m^2	Más de 100 m^2	Ns/Nc
1 persona	29,0	17,4	11,8	11,0	14,9
2 personas	18,0	32,0	29,8	27,5	30,9
3 personas	24,0	24,1	25,6	24,2	21,3
4 personas	14,0	17,5	24,1	23,1	13,8
Más de 4 personas	15,0	9,0	8,7	14,2	19,1
TOTAL	100	100	100	100	100

Fuente: D.A.D.O. 2011

**Base 4.223 accidentes en el interior del hogar*

According to the National Health Survey (2011), 8.2% respondents report an accident in the last 12 months, being accidents in the home the most frequent ones, 28.5% of the total. The importance of accidents occurring at home, lies in the fact that the most affected groups are children under 4 years of age (52%) and persons over 75 (58%). Considering all age groups, these accidents happen more frequently to women aged 55 or older.

The injury prevention programme: **Detection of home and leisure accidents** (*Detección de Accidentes Domésticos y de Ocio,* DADO) of 2011, estimates that 2,576,601 people (58.7% women and 41.3% men), or almost 5 out of 100 Spaniards suffered this kind of injury. Considering all age groups, 42.4% of the accidents suffered by women occurred while they were carrying out household work. Falls are the mechanism responsible for 51.1% of DADO accidents, with the group most affected being those over 65 years of age, and the type of fall is at ground level produced by tripping. Hospitalisations due to an injury produced by a DADO accident represent 73.1% of the total, but only 5.7% of these falls require hospitalisation, but when this happens, the average stay is 13.7 days.

More than 50% and up to 75% of falls occur at home. This is also where frail persons tend to fall the most. Several studies have shown the effectiveness of intervention on the modification of the home risks in fall prevention (Kiel, Schmader & Lin, 2014). Especially in high-risk patients who have fallen and in those with visual impairment (Herreros et al, 2012) (Rodríguez Navarro, 2012).
Both the NICE guideline on fall prevention and the British and American Geriatrics Societies include, among other recommendations, intervention on home risks as components of a fall prevention intervention.

On the other hand, another study talks about specific housing interventions. More tentatively (due to the fact that approaches to critical assessment were not described in the review and therefore the strength of the evidence cannot be determined), it was suggested that a range of very specific home interventions (for instance, pest control, radon exposure mitigation, smoke alarm installation, swimming pool fencing, water heater at safe temperature and a rental vouchers scheme) were effective means to improve the specific health outcomes of each intervention (McCartney et al., 2017).

Measures to be considered and proposal to be included in BIMhealthy

The WHO indicates that there are simple and cost-effective interventions, coinciding with those proposed by the Spanish Association for Primary Paediatric Care:

Strategy for health promotion and prevention in the NHS (Ministry of Health Social Services and Equality, Ministerio de Sanidad, Servicios Sociales e Igualdad, MSSSI, 2014):

Safety devices:

- Smoke and carbon monoxide alarms.
- Doors and fences on stairs and window protectors.
- Limitation of hot water temperature.
- Safe storage of toxic and sharp objects, to make the house a safe place.
- Fence installation in private swimming pools when children are around.
- Secure sockets.

Recommendations to prevent falls in frail elderly (MSSSI, 2014):

Distribution of the furniture in order to have no obstacles in the way.

- To remove rugs and mats or to secure rugs to the floor with a non-slip surface.
- To keep the floor free of objects.
- To roll up or tape the cables tightly next to the wall to avoid tripping.
- To use non-slip floor polish or not to use it at all.
- Surfaces throughout the home should be well illuminated both by day and night.
- To avoid too direct or dazzling artificial lights.
- Switches at the entrance of rooms and corridors should be within easy reach.
- In the kitchen, to keep utensils or accessories on low shelves (such as at waist level).
- In the bedroom, it is necessary to have a switch or lamp near the bed to avoid getting up and wandering around in the dark.
- In the bathroom, a non-slip mat should be placed on the floor of the bath or shower.
- To have handles in the bath or shower and next to the toilet and bidet.

3.3.2 Accessibility

The population pyramid in Spain continues its ageing process. According to the statistics of the Continuous Register of the Spanish National Statistical Institute (*Instituto Nacional de Estadística*, INE), on 1 January 2018 there are 8,908,151 old people, 19.1% of the total population (46,722,980) (Final data published on 22-1-2019). This situation makes it necessary to take into account the "**Useful life of the dwelling**" (also known as the life-cycle of the dwelling), and to allow the dwelling to be adaptable so that it can accommodate changes in human functioning during the life of a person, allowing the occupants to remain in their homes as long as possible. **Universal design (or universal housing)** is an approach to the design, construction and housing adaptation to meet the needs of all the occupants, regardless of their age, functioning or social situation (WHO, 2018). The aim is to prepare spaces for **a comfortable, safe and autonomous old age.**

Any accessibility action carried out at home involves collateral improvements that allow spaces in the house to be used by any person, which means a benefit for health. The use of colours and textures, order, type of life, chromotherapy and other considerations help to relax, reduce the stress levels and favour all the inhabitants of the house (García et al., 2019).

The "functional adaptation of homes" (*Adaptación Funcional de Viviendas*, AFV) can be considered to be composed of three types of interventions, each one with its characteristics and relevance: the removal of barriers in accesses and common elements of the building (stairs, corridors, lift), the adaptation by means of works inside the house, and the provision of technical aids aimed at facilitating or enabling the performance of the activities of daily life at home.

Accessible dwellings are homes where most people carry out the activities of daily life in the safest and most autonomous way possible. All human beings should be able to peacefully develop their life in their home. Therefore, applying universal accessibility, design, technological advances, transformations and laws must be the tools for houses to be adapted to the good use of all, positively influencing the health of the same (García et al., 2019).

Traditionally, accessibility has been associated with disability, but accessibility in housing is not a problem for just a few. Taking into account this factor has collateral benefits that improve the quality

of life of all those who live in the house and not only the disabled person. If use by and for people with specific needs is possible, it will be easier for those who do not have them (García et al., 2019).

Disability is a general term that describes physical or psychological impairments, which may produce activity limitations or participation restrictions (WHO, 2018).

The disabled population is increasing as the world's population grows. Disability affects low-income households disproportionately, and has a higher prevalence in low-income and middle-income countries (WHO, 2018). According to the Spanish National Statistics Institute (2019), in one out of every five Spanish households there is at least one **disabled person, 20% of households.**

By virtue of Article 27 of Law 8/1993 of 22 June on the promotion of accessibility and the elimination of architectural barriers, people with disabilities are entitled to this housing stock.
According to the Physical Disability Monitor (Observatorio de Discapacidad Física), in Spain there are 2,813,592 people with legal recognition of disability. That is, 6% of the Spanish population. In terms of housing, there is Royal Decree 173/2010, of 19 February, which modifies the Spanish Technical Building Code, approved by Royal Decree 314/2006, of 17 March, in terms of accessibility and non-discrimination of people with disabilities.

Non-accessible home environments expose people with functional impairments, risks of falls and injuries, restrict social participation, negatively affect quality of life, and increase the burden on caregivers and external social service agents. They limit the person's ability to manoeuvre in different spaces (WHO, 2018).
There are areas in the home that are particularly relevant and should be taken into account under these circumstances:

The **kitchen**: so that a disabled person **can carry out in them the maximum number of activities autonomously, without the need to ask others for help**, so that the **design must be as simple as possible.** To take care of the proper and orderly placement of furniture to allow mobility without obstacles, to control the systems for opening furniture, drawers and doors of appliances, the height of placement of accessories, to take care when choosing floor and wall

materials to avoid slips, reflections and glare and to control the light level will help people with disabilities, and all persons in general, to be able to cook and move freely in that space (García et al., 2019).

The **bathroom**: this is the place where most attention should be paid to in order to facilitate its use and minimise the dangers and risks that can occur in daily tasks (García et al., 2019). Especially with regard to the shower or bath. It is the place where basic, vital and essential activities of the daily life are carried out, and not only the physiological functions, but also others that are related to the body and its care. All of them are very intimate and personal, and they entail some risks such as slips and falls, since they are carried out in least favourable conditions, such as a moist atmosphere, water and wet floors, the use of soaps and gels, the possibility of being without clothes, etc. (García et al., 2019). To consider the accessibility in this space allows all people to be as autonomous as possible, to perform the different actions and to use the sanitary appliances more safely and to enjoy a better quality of life (García et al., 2019).
In order to establish a clear guidance on maximising health gains associated with accessible housing, a systematic review of the evidence on the **effects of accessibility on health** was conducted.

People with **functional impairments** who live in **accessible home environments are healthier** and in better conditions to perform **everyday tasks in an independent way** than the ones who live in conventional or inaccessible home environments (WHO, 2018).
The GDG assessed the certainty of evidence to indicate the extent to which the research supports the recommendation and, in general, the certainty of evidence of interventions to improve the accessibility and usability of the homes of people with functional disabilities is moderate, supporting the decision to provide a strong recommendation. This general certainty arises from a consideration of the overall evidence, which **suggests important benefits for this disadvantaged population**, although the evidence is of low certainty for some interventions and outcomes.

Regarding the specific aspects of the outcomes of the systematic review and other information, the certainty of the evidence that people with functional impairments are in better conditions to perform activities of daily life when they live in accessible environments was assessed as low to moderate to the certainty of the evidence that, regarding persons with some functional impairment, it is less likely that impairments decrease and that they get injured when living in accessible environments.

The certainty of the evidence that indicates that living in accessible environments reduces mortality of people with functional impairments was assessed as low; and the certainty of the evidence that people with functional impairments experience positive psychological effects and a better quality of life when they live in accessible environments was assessed as low to moderate.
After considering the certainty of evidence, the balance of benefits and harms related to increasing the supply of accessible housing, and the feasibility of increasing the supply of accessible housing, the GDG made a strong recommendation:

This recommendation was informed by a systematic review of the evidence on the impact of accessible housing on residents with functional or cognitive impairments. The systematic review and the GRADE tables used to assess the certainty of the evidence are available online at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html, Web annex F.

Twenty studies, including six randomised trials, were eligible for the systematic review. Almost all studies focused on people with functional impairments, with only one study of people with cognitive impairments. The interventions implemented to improve the characteristics of home accessibility were carried out as a single intervention or as a part of a multi-component programme. Home modifications focused mainly on **architectural changes or equipped devices** (such as grab bars) that focus on **mobility problems.** Some of them focused on lighting improvements or vision-directed adjustments (WHO, 2018).

Table 8: Research recommendations: accessibility

Current state of the evidence	There are relatively few high-quality studies, with most studies to date being observational or small. The participants and types of intervention reviewed vary greatly. Some studies rely on subjective self-reporting rather than objective performance-based measures, and use different psychometric instruments to identify quality of life outcomes. There are few studies conducted outside of high-income settings, and most of the research focuses on the experience of adults. For some studies, it is not clear which component of the intervention was most effective. Future studies might consider using factorial designs to enable analyses of the effects of the specific interventions that make up a multicomponent intervention. Longitudinal studies, using standardized outcome measurements, are required to provide a stronger evidence base for the health and social benefits of home accessibility interventions.
Population of interest	Populations with a range of physical and cognitive impairments. Much of the current evidence is based on research with adults with physical impairments in high-income settings; future research should consider people with cognitive impairments, people in low-income settings, and children and young adults.
Interventions of interest	Improving accessibility of housing. This could include modification of specific furniture and fixtures in the house; structural changes to the inside and immediate outside of the house; and assistive devices that are part of the house. Studies should consider how different accessibility features affect health and social outcomes for people with specific impairments. Research should determine which accessibility features affect these outcomes for people with different impairments.
Comparisons of interest	Groups living in accessible and conventional/unmodified home environments; a group before and after intervention.
Outcomes of interest	Injury rates (especially falls), well-being and quality of life, mental health and depression, dependency on external social or care services, and social participation.
Time stamp	Current systematic review on the association between accessible home environments and the health of people with impairments included studies published up to April 2018.

The reviewed research suggests that living in accessible homes improves the health of people with disabilities. However, the high-quality research in this area is difficult, since assigning people to a control group is not always possible.

Measures to be considered and proposals to be included in the BIMhealthy tool.

Minimum measures set out in the regulations are proposed to ensure universal accessibility.

- **Doors and openings** must have a minimum **opening width** of **0.80m** and a **height** of at least **2m**. *The installation of sliding doors greatly facilitates accessibility.*
- Doors **handles** system should be operated either by **pressure** or **lever** mechanisms.
- The **taps** must be operated by **pressure** or **lever** mechanisms.
- **Corridors** must be at least **1.20m wide**. A **minimum diameter of 1.50m** is required to ensure that people in wheelchairs can move correctly without incidents.
- **Kitchens** must be between **0.00 and 0.70m high** from the floor, with a minimum **turning space** of **1.50m.**
- The approach space in the **bedrooms** to the bed must be at least **0.90m** and the front space to the wardrobe at least **1.20m.** It should not be forgotten that the interior of this room should have a space that allows a circle of **1.50m diameter.**
- Mechanisms such as **stopcocks**, **electrical devices**, **sockets**, **intercoms or doorbells or furniture**, among others, should be placed at a height between **0.40-1.4m** from the floor. The distance from the **corners** must be **0.60m**.
- The **handles** must be placed at an appropriate distance, so that they can be used to maintain balance.
- The **floors** must be non-slip and free of irregularities or obstacles.
- The **reference height** is that of a **work table**, the **kitchen counter,** or should not exceed **0.85m**.
- The **interior of the cupboards** should be organised so that the objects most frequently used are easily accessible.
- In front of the **kitchen door and in front of the sink**, it must be possible to make a 1.20-diameter turn, free from any obstacles.
- In the **bathroom**, the **sink** must be accessible **from the front** and the **shower from the side.** The floor must be **non-slip when dry and wet.**
- The **washbasin** must not have a pedestal, it must be placed at **0.80m** from the floor and have a **free height under it** of **0.65m** to allow access.
- The **shower** must have support and grab bars, as well as a seat or bench inside and be at ground level.

Regarding the descriptions of the accessibility features (source WHO, 2018), the following must be taken into account:

- Aimed at hygiene facilities (installation of support bars in the bath or shower, replacing the bath with a shower), entrances including balcony and patio, stairs and doors (automatic door openers). We find few adaptations aimed at floor surfaces and bathrooms.
- Wheelchair accessible doors, ramps, rails, bath seat in bathrooms, non-slip surface.
- Handrails, grab bars, ramps, hand shower, raised toilet, roll-in shower, widened door, relocating laundry facilities to ground floor, bed rails, designated parking area (car park) on street.
- Lever handles on doors.
- Additional lighting.
- Security features (locks, smoke detectors) and adaptive equipment (handles, bath benches).
- Lighting adjustments in the kitchen, bathroom, living room and lounge.
- To reduce glare, to improve lighting.
- To paint the edge of the steps.
- To install support bars, stair rails.
- To remove or replace loose mats, to eliminate clutter.
- Minor adaptations: handrails, rails.
- Important adaptations: stair lifts, bathroom conversions providing levelling of the shower access, extensions to provide a ground floor bedroom, bathroom or both, stair and floor lifts, downstairs bathroom facilities, door widening, ramps, kitchen alterations.
- Installation of support bars, rails, raised toilet seats.

3.3.3 Crowding

Healthy housing contributes to the social and psychological development of its inhabitants and minimises the psychological and social stress factors related to the area around the home. From the earliest times, the home has been a refuge for human beings, a shelter from physical risks and dangerous animals, from the rigours of the daily work and stress factors resulting from social interaction, a place of privacy and intimacy. Therefore, the healthy house must have sufficient living space, privacy and comfort, convey the impression of personal and family security, provide space for recreational activities and community services, and a location that allows to reduce noise exposure (Santa María, 2008).

Depending on the cultural context, the inhabitant's perception of an overcrowded house may vary and different standards may be applied to determine the appropriate living space. The table 3.1 provides an overview of the WHO Housing and health guidelines of different measures of crowding that can be applied to assess the prevalence and level of crowding in different settings.

Regarding this point, how do social factors such as crowding influence people's health?

In the general population exposed to crowding, what is the exposure-response?

A systematic review was conducted to study the relationship between exposure to crowded housing and the proportion of people in poorer health compared to the population not exposed to crowded housing. Five key outcomes were considered for this review (Shannon et al., 2018):

- Result 1: Tuberculosis (TB), other infectious diseases.
- Result 2: Intestinal diseases: Gastroenteritis/diarrhoeal diseases.
- Result 3 and 5: Mental health, including stress.
- Result 4: Sleep disorders

Table 9: Measures of crowding

UN-Habitat
Overcrowding occurs if there are more than three people per habitable room *(88)*.
American Crowding Index
Crowding occurs if there is more than one person per room; severe crowding occurs if there are more than 1.5 persons per room (excluding bathrooms, balconies, porches, foyers, hall-ways and half-rooms) *(89)*.
Argentinian National Institute of Statistics and Censuses
Overcrowding represents the quotient between the total number of people in the home and the total number of rooms or pieces of the same *(90)*. Households with critical overcrowding are considered those with more than three people per room (excluding the kitchen and bathroom) *(91)*.
Canadian National Occupancy Standard
Overcrowding occurs if extra bedrooms are required to ensure that each of the following have their own bedroom: • cohabiting adult couple • lone parent • unattached household member aged 18 years or over • same sex pair of children aged under 18 years • each additional boy or girl in the household (unless there are two opposite sex children under 5 years, in which case they can share a bedroom) *(75)*.
British Bedroom Standard
Overcrowding occurs if extra bedrooms are required to ensure that each of the following have their own bedroom: • cohabiting adult couple • person aged over 21 years • same sex pair of children aged 10–20 years • two children aged less than 10 years • two children where one is aged 10–20 and one is aged less than 10 years • any other person aged under 21 years that is not paired under one of the preceding categories *(76)*.
Eurostat
Overcrowding occurs if the household does not have at its disposal a minimum number of rooms equal to: • one room for the household • one room per couple in the household • one room for each single person aged 18 years or more • one room per pair of single people of the same gender between 12–17 years • one room for each single person between 12–17 years and not included in the previous category • one room per pair of children under 12 years *(74)*.

EUROSTAT, in this case, takes into account the fact that the situation of crowding does not have the same effect **according to the age, gender** and **kinship of the persons who occupy the household**.

Relationship to Tuberculosis, TB: This studies were consistent in showing that **crowding is associated with increased risk of TB**, although the positive association was not statistically significant in a small number of studies.

Other no-TB infections: Definitions of crowding in these studies were variable and based on persons/room, rooms/house, square metres of living space or living in single or multiple rooms. In most outcomes, the risk of **non-TB infectious diseases was associated with crowding.** Given the range of outcomes identified, it is difficult to draw definitive conclusions on each outcome due to the small number of studies.

Intestinal diseases: Overall, the evidence suggests that **crowding may be associated with gastroenteritis and diarrhoeal diseases**, but the data are not completely consistent.

Mental health and depression: Mental health is more likely to become deteriorated in the most crowded conditions. Taking into account the systematic review conducted by the WHO, we find that this evidence suggests that crowding may be related to milder forms of **mental health.** Problems such as **stress and unhappiness feelings**. This also leads to the issue of whether relieving crowding at home can lead to improvements in mental health.

In a study by Wells and Harris (2007), low-income women who moved into recently constructed houses reported **significant improvements in psychological distress as a result of reduced crowding.** The study was excluded from this review because the authors did not use a purely quantitative measure of crowding. However, more researches, which consider the effect of improvements in crowding on mental health outcomes, would be of value.

Two types of exposure-response relationships may be interesting. Firstly, it can be assumed that living in crowding conditions for a longer period would lead to a poorer mental health.

In relation to living in crowding conditions for shorter periods, there is only one study. Barnes, 2011, investigated this hypothesis. This study found that children living in a house full of people between three and five years were significantly more likely to be unhappy with their health. Nevertheless, there was no difference in outcome for those who had never lived in a house full of people and those who had lived in a hose full of people for one or two years in the previous five years. This suggests that **worse mental health outcomes can only arise from spending longer periods of time in crowded living conditions.**

Few studies have explicitly investigated this exposure-response relationship. These studies have not established a clear exposure-response relationship. Faisal-Cury (2009) found that participants in very crowded households were more likely to show symptoms of common mental disorders than those living in less crowded homes. Nonetheless, participants living in households having between 0.76 and one person per room were also more likely to report symptoms of common mental disorders, while those in slightly more crowded households were not. In their prospective cohort study, Regoeczi et al. (2008) explored non-linear relationships between crowding and mental health outcomes. They found that both those living **in an empty home and those living in very crowded homes were associated with increased chances of depression.** In addition, when the analysis was divided by gender, **women in very crowded households were more likely to be depressed**, while men were less likely to be depressed. On the other hand, men were more likely to report symptoms of depression in very crowded households.

Sleep disorder: Two recent cross-sectional studies (Chambers 2016, van der Spuy 2017) and an ecological study (Johnson 2015) investigated the associations between crowding and sleep disorders. A cross-sectional study found excessive daytime sleepiness with >1 person per room (van der Spuy 2017). Another study concluded that living in a crowded household (≥ 1 person per room) is not significantly associated with relevant outcomes for sleep disorders, but found a significant relationship between crowding and sleep duration in some analyses (Chambers 2016). The ecological study found a significant positive relationship between the percentage of crowding at neighbourhood level (>1 person per room) and the apnoea-hypopnoea index (Johnson 2015).

In several documents, crowding was included as a confounding factor, and the text simply reported that it was adjusted in the analysis (together with other confounding factors), but it did not show the magnitude of the association of crowding with health outcome. On other occasions, the articles reported only those associations that were statistically significant.

In addition, few of the studies identified in this review could be labelled "high quality", and therefore the results of the study should be interpreted in light of these limitations.

Measures to be considered and proposal to be included in BIMhealthy

Based on EUROSTAT recommendations:

- One living room for the home (equivalent to a lounge).
- One room per couple in the home.
- One room for each single person over 18 years of age.
- One room for every two persons of the same gender between 12 and 17 years of age.
- One room for each person between 12 and 17 years old not included in the previous category.
- One room for every couple of children under 12.

3.4 Socioeconomic housing environment. Causal factors based on evidence. Measures to be considered and proposals to be included in the BIMhealthy tool

3.4.1 Social inequity

CAUSAL FACTORS BASED ON EVIDENCE

For many years, the housing environment has been recognised as one of the main elements affecting human health. The buildings we live in, the neighbourhoods in which they are located and the regions to which they are linked determine, for example, the quality of our indoor air, the access we have to healthy food, recreational facilities and paid employment (Ranson, 2002).

The quality of life, understood as the degree of excellence of life that a given society, precisely located in a time and in a geographical space, offers in its policies of allocation, and spatial and social distribution of resources destined to satisfy directly or indirectly a certain range of human needs (including the non-material ones) for all its members, and in the consequent level of individual and group satisfaction or dissatisfaction according to the perception of that offer, accessibility and use, as well as of the potential and real consequences felt or not by the population involved. The final effects of quality of life take the form of the physical and mental health of the population as well as of the housing as a health agent (Rojas, Ciuffolini & Meichtry,2005).

Living in places that have assured access to basic goods, with high social cohesion, designed to promote physical and psychological well-being and protect the natural environment, is essential for equity in health. The importance of green and recreational areas and time spent outdoors has also been noted as determinant of good health. The design of the living environment must take into account the needs of the population, and particularly those of the most vulnerable groups such as the elderly or people with disabilities. In Spain, in the last decade, the access to housing has become one of the biggest problems due to the spectacular increase in housing prices and the consequent indebtedness and economic problems of the families in the country with the highest proportion of families with home ownership in Europe. This situation may have resulted in an increase in health problems related to the need to extend working hours to face high mortgages or the economic vulnerability that forces the working population to accept harsh working conditions in a context of growing unemployment. Other effects of high pricing with a potential impact on health have also

been an increase in socio-economic and origin-based segregation between neighbourhoods, and a delay in the transition to adulthood among young people, with consequences for their social health, understood, among other things, through indicators such as the decision to live with a partner or to have children. Living to pay for housing has become the material reality for many families, thus threatening the possibility of fulfilling other rights (Spanish Ministry of Health and Social Policy, 2010).

There is ample evidence that **housing conditions** may have an impact on **people's physical and mental health.** The impact of the current economic crisis on access to adequate housing has been particularly strong in the increase of households with problems to face housing costs, which has led to an increase in the number of evictions and homelessness. These consequences have been felt more acutely in Spain, where the housing system does not guarantee access to families with fewer economic resources. The current residential crisis in Spain could be mitigated in the short term by policies aimed at reducing the number of evictions, such as those based on facilitating the payment of the debt or surrendering in lieu of foreclosure. In the long term, it would be desirable to promote the creation of a quality social housing stock and a system of rent subsidies, which are highly underdeveloped instruments compared to other European countries (Novoa, Bosch, Díaz, Malmusi, Darnell and Trilla, 2014).

The social structure determines inequalities in the intermediate factors, which in turn determine health inequalities.

Barriers to maintaining a healthy diet include prices, the scarcity of vegetable and fruit shops in some neighbourhoods, culinary knowledge and time available for cooking. Low-income populations eat less fruits and vegetables and childhood obesity is more common in families with low education level (Spanish Ministry of Health and Social Policy, 2010).

On the other hand, the design of the building has the potential to cause stress and eventually affect human health (Evans and McCoy, 1998).

For the realisation of healthy housing, it is essential, on the one hand, to consider the family, its lifestyles and the role people's subjectivity plays. On the other hand, a way of intervention from a speech of articulation with the speeches of others, a story that is unifying without being dominant and that can guide the emancipatory speeches that are around a common process of the object and

the subject of knowledge for health. The following points should be considered (Rojas, Ciuffolini & Meichtry,2005).

- The quality of life, health, housing and risk shape the notion of healthy housing and are cultural facts, which is why the responsibility that human beings and institutions have in their production, distribution and consumption must be noted.
- The inhabitants of housing can denote the capacity to adapt in order to absorb risks without their health being affected (resilience) or their inability to adapt to such change, leaving them exposed to situations of vulnerability and risk.
- The analysis of vulnerability must consider the factors that originate it: exposure, social fragility and level of resilience.
- In order to reduce social vulnerability and the risk of housing for health, intervention strategies based on intersubjectivity must be applied.

The intermediate factors are determined by the social structure and include firstly the material resources that are detailed below (Spanish Ministry of Health and Social Policy, 2010).

- Employment conditions (work situation, precariousness) and work (physical and ergonomic risks, organisation and psychosocial environment).
- The burden of unpaid work (household and caring work).
- The level of income and the economic and patrimonial situation.
- The quality of the housing and its facilities.
- The neighbourhood or area of residence and its characteristics. Regardless of the inequalities among individuals, there are also geographical variations in health, related to the social, economic and health resources available in each region. Life expectancy at birth exceeds 80 years in many of the countries with the highest per capita income, and it does not reach 50 years in the poorest countries.

The quality and access to healthy food is also largely determined by the environment. Families living in low-income neighbourhoods have difficulties in buying healthy food. Residential instability can be defined as the lack of stable housing, either through frequent moves, living “doubled up” with many families sharing a living space or homeless people in refugee situations (Spanish Ministry of Health and Social Policy, 2010).

A research argues that the subjective environment, evaluated through the perceived residential satisfaction, has a greater influence on psychological well-being than the objective environment. Residential satisfaction takes advantage of individual evaluation of the conditions of its residential environment, in relation to its needs and expectations (Sandel and Wright, 2006).

Stimulation, consistency, ability to pay, control and restoration are a preliminary set of environmental dimensions interrelated to stress. Each of these dimensions, in turn, consists of explicit elements of interior design. A better understanding of those dimensions along with a greater knowledge of their underlying physical properties may allow for unintended attention or curiosity. Fascination helps to recover by ignoring the potential role of designed environmental stocks depleted by sustained concentration or efforts to contribute to human health (Evan & McCoy, 1998).

There is ample evidence that housing conditions may have an impact on people's physical and mental health. The impact of the current economic crisis on access to adequate housing has been particularly strong in the increase of households with problems to face housing costs, which has led to an increase in the number of evictions and homelessness. These consequences have been felt more acutely in Spain, where the housing system does not guarantee access to families with fewer economic resources (Novoa et al., 2014).

Poor physical housing conditions have been linked to negative mental health among children and their adult caregivers. A number of housing characteristics, including floor level, presence of pests and humidity have been associated with psychological problems, poor mental health and lower health status. Noise exposure inside and around the house has been associated with higher cortisol levels and greater perceived stress. McCarthy et al. found that age of housing, type of housing (apartments versus single-family homes), floor level and location affected respiratory (that is, coughing, wheezing and self-reported asthma) and mental health outcomes. Another study relates home humidity and the inability to keep the house warm enough in the winter to an increase in the prevalence of asthma among adults. The research has consistently shown that home ownership is associated with higher health qualifications. Wont et al. showed that perceived psychological distress improved after the homeless adults were placed in permanent housing. The influence of movement on health may be partly mediated by the individual's perception of change in their environment. A recent study found that subjects who perceived an improvement in environmental quality of housing after moving reported better self-care qualifications. Social relationships, social

supports and social networks can work as a cushioning system that can counteract the negative effects of environmental stressors. Housing instability and homelessness disrupt social networks, which can have a negative impact on mental health. However, increased social support alone may not be adequate to buffer the deterioration of mental health caused by high levels of housing stressors (Sandel & Wright, 2006).

Along with conditions at home, conditions in the neighbourhoods where houses are located can also have powerful effects on health. Social factors, physical factors and, increasingly, as has been shown, the economic characteristics of neighbourhoods affect the quality and longevity of health in the short and long term. The physical characteristics of a neighbourhood can promote health by providing safe places for children to play and for adults to exercise, free from crime, violence and pollution. The access to supermarkets that sell fresh products, in addition to having fewer liquor and convenience stores and fast food places, can make it easier for families to find and eat healthy food. Social and economic conditions in neighbourhoods can improve health by allowing access to job opportunities and public resources, including efficient transport, an effective police force and good schools. Neighbourhoods with strong ties and high levels of trust among inhabitants can also strengthen health. However, not all neighbourhoods benefit from these opportunities and resources, and access to neighbourhoods with conditions that promote health varies according to the household's economic and social resources. Housing discrimination has limited the capacity of many low-income families and minorities to move into healthy neighbourhoods. The concentration of poor housing in disadvantaged neighbourhoods further aggravates racial, ethnic and socio-economic health disparities (Cubbin, Egerter, Braveman and Pedregon, 2008).

It is well known that the well-established connections between poor housing and poor health indicate that housing improvements can be an important mechanism through which public investment can lead to improved health. Intervention studies that have evaluated the impact of housing improvements on health are an important source of data to test assumptions about the possibility of health improvements. Data from studies of heating interventions and energy efficiency indicated that improvements in general health, respiratory health and mental health can be found. Studies targeted at patients with inadequate heating and chronic respiratory disease were more likely to report improvements in health (Thomson, Thomas, Sellstrom and Petticrew, 2009)

The current residential crisis in Spain could be mitigated in the short term by policies aimed at reducing the number of evictions, such as those based on facilitating the payment of the debt or surrendering in lieu of foreclosure. In the long term, it would be desirable to promote the creation of a quality social housing stock and a system of rent subsidies, which are highly underdeveloped instruments compared to other European countries (Novoa et al., 2014)

There are health benefits from food stores (fruits and vegetables, meat and fish, daily groceries) and coffee shops that are close to where people live. People can walk or cycle to these food stores, where they can connect with others in their community. This is particularly important for older and disabled people who may not have access to motor vehicles. On the other hand, apart from what is learned at school, including life skills and health education, there are health benefits associated with the physical presence of schools within communities. Schools can provide an important social focus in communities. Children, parents and grandparents can develop a social network around the school. Schools are also an unparalleled opportunity to promote children's health. When schools are located near children's home, and when there are safe roads to school, children are more likely to walk or cycle to school. And last but not least, spaces (both outdoor and indoor) for recreation and social interaction are a valuable community resource. Parks and community rooms are places where groups can meet, play and organise themselves to work together on projects and activities. People who have good access to attractive open spaces are more likely to be physically active (Capon and Blakely, 2007).

Measures to be considered and proposals to be included in the BIMhealthy tool.

Information in this regard will be included in the guide. No parameters are included in the BIMhealthy tool.

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