Review on 21st century challenges and IoT solutions for everyday life

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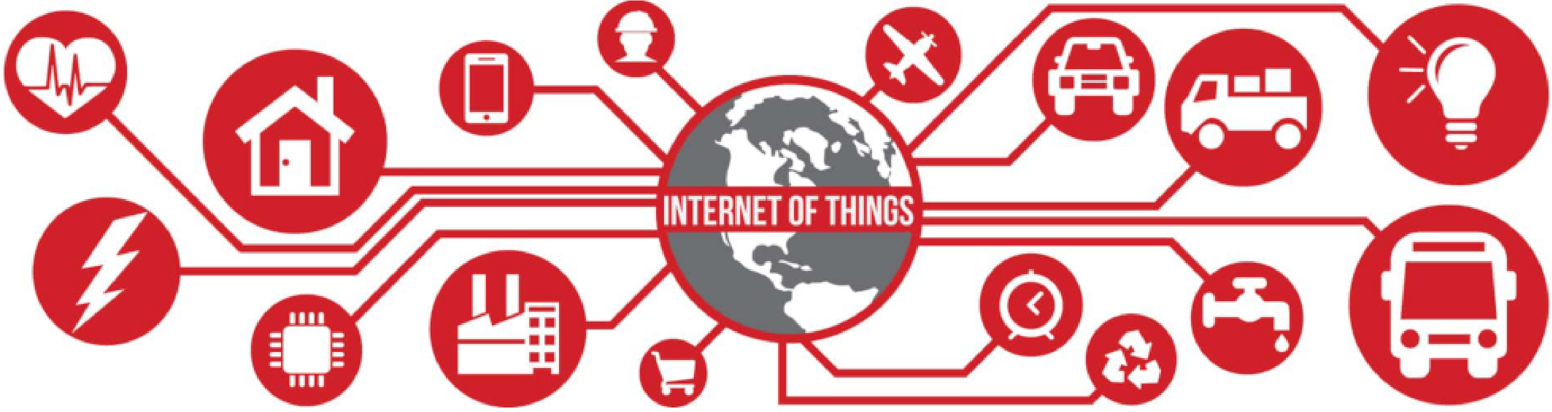

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1. Smart cities

According to UN demographic projections, by 2059 the world's population will exceed 10 billion. Such a rapid growth makes it necessary to create solutions that will enable rational management of resources, increase in food production and improvement of ecology while maintaining the high standard of living expected by the population.

One of the key challenges facing politicians, architects and engineers is urbanization. The urbanization index, which determines the percentage of city residents in the total population, is approximately 74% for Europe, which shows that the majority of population lives in cities and not rural areas. Hence, the key aspect is to ensure that the city functions in such a way that it is ecological, effective and comfortable for its inhabitants. The idea of smart cities comes to the rescue, which is based on the use of the Internet of Things (IoT) to ensure more efficient functioning of cities. This idea has evolved over the years, introducing three main generations of smart cities:

- **Smart Cities 1.0** - the first concepts of smart cities, which focused on the greatest possible use of new technologies, mainly a huge number of sensors connected to the network, which were to constantly send data for analysis. This approach did not focus on actually defining existing needs and solving them, but rather on creating completely new cities planned from scratch using IoT technology. Examples of such cities are: Masdar in the United Arab Emirates and Songdo in South Korea.
- **Smart Cities 2.0** - currently the most popular generation of smart cities, in which local authorities are looking for IoT solutions to solve current city problems, e.g. intelligent traffic control to eliminate traffic jams. Examples of cities using the approach described above are Barcelona and Rio de Janeiro.
- **Smart City 3.0 ("Human Smart Cities"/"Sharing Smart Cities")** - the third generation of smart cities was created quite recently (2015) and places particular emphasis on social initiatives. In this variant, local authorities create space for citizens to solve the problems they encounter in the way citizens prefer. Therefore, in addition to large projects, emphasis is placed on small, grassroots initiatives. In this variant, it is also key to educate the public to encourage them to use modern technologies and to create their own solutions based on open-source technologies.

In this chapter, we will focus on selected problems of large cities where IoT technologies can help solve them as inspiration to large projects and also small initiatives.

1.1 Transport and mobility

When examining various forms of using inland transport, it can be noticed that the passenger car is still the dominant form of transportation for passengers. In drawing no. 1.1 rounded statistical data from Eurostat (as of 2018) are presented, showing the percentage share of passenger-kilometers traveled by: passenger cars (gray), buses and coaches (yellow) and trains (green). Based on the above-mentioned data, it can be seen that the dominant form of transport is the passenger car (over 80% regardless of the year) and this trend persists regardless of the year.

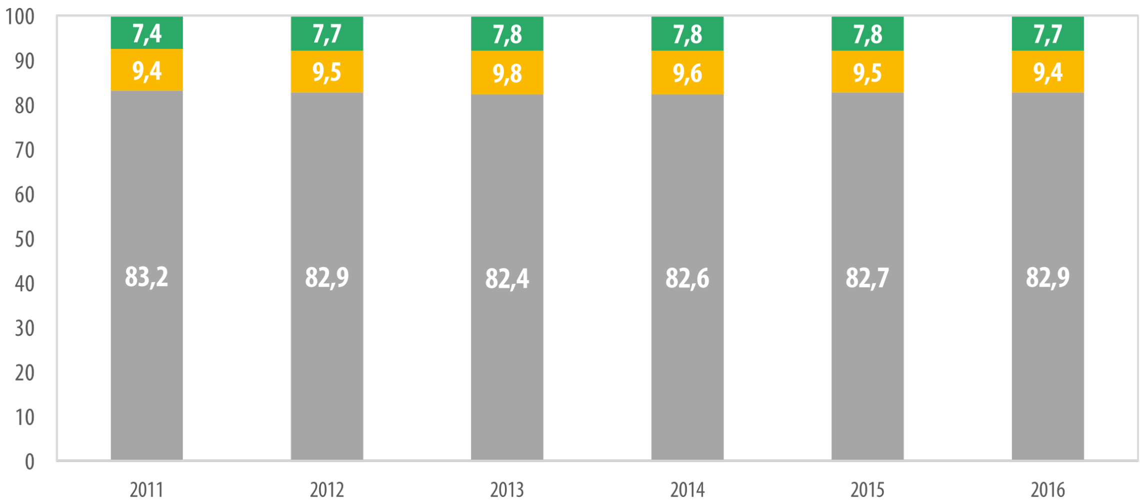


Figure 1.1: The percentage share of passenger-kilometers traveled by different way of transport. Source of image: https://op.europa.eu

The use of passenger cars for transportation is much lower in cities than in non-urban areas, but the significant use of passenger cars still causes major traffic jams in cities. According to the TomTom Traffic Index, 9 of the 20 most congested cities in the world are located in Europe (see Figure 1.2).

Some cities have started to implement IoT solutions to improve the use of public transport instead of private cars, which has affected the average length of traffic jams in these cities, e.g.

- Vienna (Austria; position 48 in the TomTom Traffic Index 2023 world ranking)- traditional buses were replaced by electric buses using renewable sources. In addition, an application was introduced that allows residents to track street traffic.
- Copenhagen (Denmark; position 160 in the TomTom Traffic Index 2023 world ranking) - integrated pedestrian, bicycle and car transport was introduced, i.e. Park&Ride and Bike&Ride.
- Gdańsk (Poland) - the TRISTAR system was introduced, which monitors public transport routes and informs passengers about the departures of public transport vehicles. In addition, an autonomous bus was tested on selected routes, transporting 8 residents without a driver on board.
- Tampere (Finland; position 201 in the TomTom Traffic Index 2023 world ranking) - the city authorities plan to introduce autonomous buses developed by Roboride, which are to run on regular routes in the city.

Rank by filter	World rank ▼	City	Average travel time per 10 km ▼	Change from 2022 ▼	Congestion level % ▼	Time lost per year at rush hours ▼	Average speed in rush hour ▼
1	1	**London** United Kingdom	**37 min 20 s**	+ 1 min	45	148 hours	14 km/h
2	2	**Dublin** Ireland	**29 min 30 s**	+ 1 min	66	158 hours	16 km/h
3	3	**Toronto** Canada	**29 min**	+ 50 s	42	98 hours	18 km/h
4	4	**Milan** Italy	**28 min 50 s**	+ 20 s	45	137 hours	17 km/h
5	5	**Lima** Peru	**28 min 30 s**	+ 1 min 20 s	61	157 hours	17 km/h
6	6	**Bengaluru** India	**28 min 10 s**	- 1 min	63	132 hours	18 km/h
7	7	**Pune** India	**27 min 50 s**	+ 30 s	57	128 hours	19 km/h
8	8	**Bucharest** Romania	**27 min 40 s**	+ 20 s	55	150 hours	17 km/h
9	9	**Manila** Philippines	**27 min 20 s**	+ 20 s	46	105 hours	19 km/h
10	10	**Brussels** Belgium	**27 min**	+ 20 s	37	104 hours	18 km/h
11	11	**Taichung** Taiwan	**26 min 50 s**	- 10 s	35	71 hours	20 km/h
12	12	**Rome** Italy	**26 min 30 s**	+ 40 s	41	107 hours	19 km/h
13	13	**Mexico City** Mexico	**26 min 30 s**	+ 50 s	63	152 hours	18 km/h
14	14	**Sapporo** Japan	**26 min 30 s**	- 1 min 10 s	34	75 hours	20 km/h
15	15	**Bordeaux** France	**26 min 30 s**	+ 20 s	43	111 hours	18 km/h
16	16	**Paris** France	**26 min 30 s**	+ 20 s	46	120 hours	18 km/h
17	17	**Kaohsiung** Taiwan	**26 min**	+ 20 s	32	68 hours	21 km/h
18	18	**Turin** Italy	**25 min 40 s**	+ 40 s	31	92 hours	20 km/h
19	19	**Bogota** Colombia	**25 min 30 s**	- 50 s	50	117 hours	20 km/h
20	20	**New York** United States of America	**24 min 50 s**	+ 20 s	43	112 hours	20 km/h

Figure 1.2: The TomTom Traffic Index 2023 world ranking. Source: https://www.tomtom.com/

- Paris (France; position 16 in the TomTom Traffic Index 2023 world ranking) - the “Grand Paris Express” project is being implemented in this city, which aims to rebuild local transport by, for example, building four additional metro lines and approximately 200 km of railway lines connected by a 100% automatic metro system.
- Neuhausen (Switzerland) - they were the first to introduce an autonomous bus running on a regular route in 2018 (see left Figure 1.3).
- Stavanger (Norway; position 261 in the TomTom Traffic Index 2023 world ranking) - they are the first to introduce a full-size autonomous bus, which is 8 meters long and can accommodate about 20 passengers (see right Figure 1.3).
- Malmö (Sweden; position 207 in the TomTom Traffic Index 2023 world ranking) install a connected public bus system. The system gathers real-time information about the whereabouts of individual buses. Based on that it informs passengers about the best routes to their destination and also connects the buses with traffic lights and each other.

Figure 1.3: Left: The first autonomous bus line in Neuhausen. Source: www.swisstransitlab.ch. Right: the first big autonomous bus in Stavanger. Source: www.forbes.com.

In addition to ecological or autonomous vehicles, solutions aimed at improving transport efficiency and safety also deserve attention. One of such solutions is Intelligent transportation system (ITS), which aims to improve traffic safety and manage traffic lights and road signs adapted to the current road situation. The concepts of the ITS are shown in Figure 1.4.

The ITS works using various wireless communication technologies to ensure greater road traffic safety by detecting collisions based on the relative position of vehicles in relation to each other and vehicles in relation to the architecture. Moreover, based on the location of vehicles, the ITS enables analysis of road traffic density in real time, which contributes to more efficient navigation of vehicles so that they move at the optimal time between two locations. An important element of the ITS is the efficient management of traffic lights, which reduces traffic jams and the adaptation of road signs to current road conditions, which improves safety. In addition to amenities dedicated to passenger cars, the ITS also focuses on other forms of communication (buses, railways and shipping). Particularly important are issues related to public transport, the effective operation of which results in greater use of public transport, reducing the number of passenger cars.

Another issue related to safety and ecology is street lighting. Well-chosen lighting

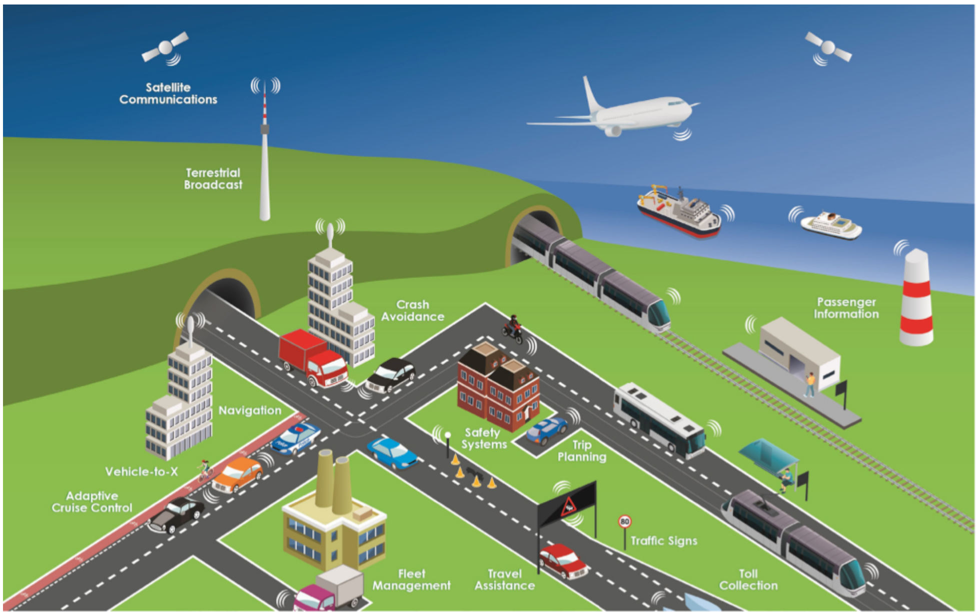


Figure 1.4: Concept of Intelligent Transport System (ITS). Source: https://www.etsi.org/

contributes to road safety and the visibility of pedestrians moving on pedestrian crossings or along streets (especially in non-urban areas). The idea of smart lights is shown in Figure 1.5. Intelligent lights turn on when motion is detected, but also depending on weather conditions, e.g. on cloudy days earlier than on sunny days. The use of such a solution not only reduces lighting electricity consumption, but also improves safety because the lighting is adjusted to current weather conditions.

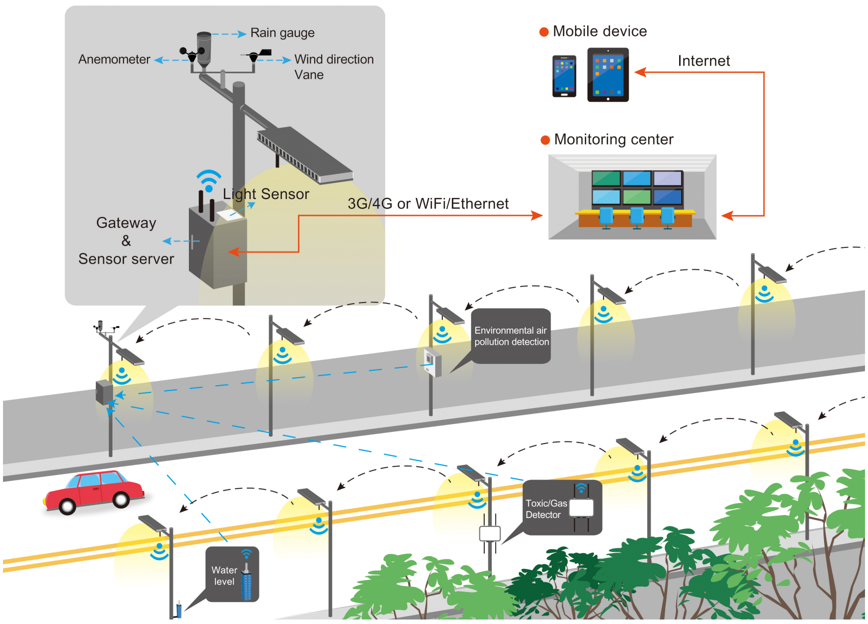


Figure 1.5: The idea of smart street lights. Source: Taiwan Sourcing Service Provider. (2015) Green ideas technology introduces blind-spot-free smart lighting control system.

An interesting solution that can enrich the ITS are intelligent pedestrian crossings (see

Figure 1.6). This means that when a pedestrian approaches the crossing, the pedestrian crossing and the road are illuminated. Warning signs are illuminated to inform the driver that there is a pedestrian in the crosswalk. Additionally, sounds are emitted to warn pedestrians that a car is approaching.

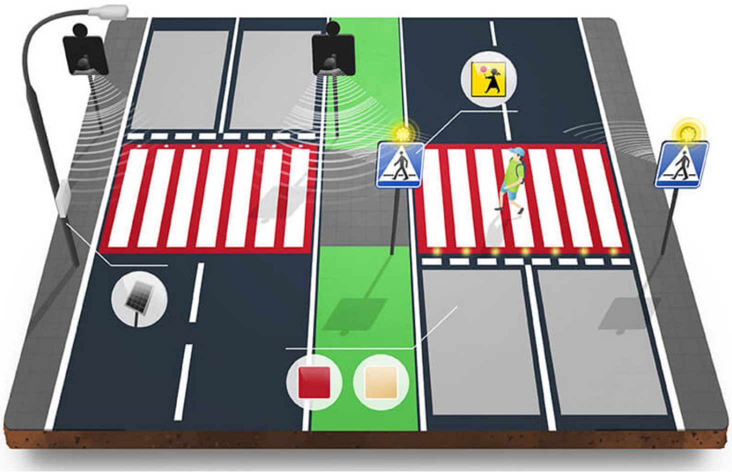


Figure 1.6: The idea of intelligent pedestrian crossings. Source: https://www.eeis.ae.

The pandemic has changed the way of shopping, increasing the number of goods purchased online and thus increasing the number of courier shipments. To reduce traffic jams, it is worth looking at the concept of parcel delivery in a way other than the traditional one, e.g. by using drones or robots. Estonia is the leader in the use of robots to deliver parcels, with such a solution in the medieval part of Tallinn. The pilot project is being carried out in cooperation with the city hall, DHL Express Estonia and Cleveron Mobility AS (constructors of the multi-functional vehicle shown in Figure 1.7).

Figure 1.7: The multi-functional vehicle used to deliver packages. Source: https://www.smartcitiesworld.net

1.2 Resource management

A key aspect of the functioning of smart cities is the rational management of raw materials such as energy, water and food. The production possibilities of these resources are limited, hence a number of actions should be introduced to reduce electricity consumption and reduce water and food waste. An important aspect of the functioning of cities is also the recovery of materials from municipal waste.

In the following subsections, we will present several problems and concepts related to the management of the mentioned raw materials.

1.2.1 Energy

More than 80% of the electricity produced is used in cities, which means that this is where solutions to reduce energy consumption should be sought. The main three areas in which electricity is used in cities are:

1. Residential and commercial buildings
2. Transport
3. Heating and air conditioning of buildings

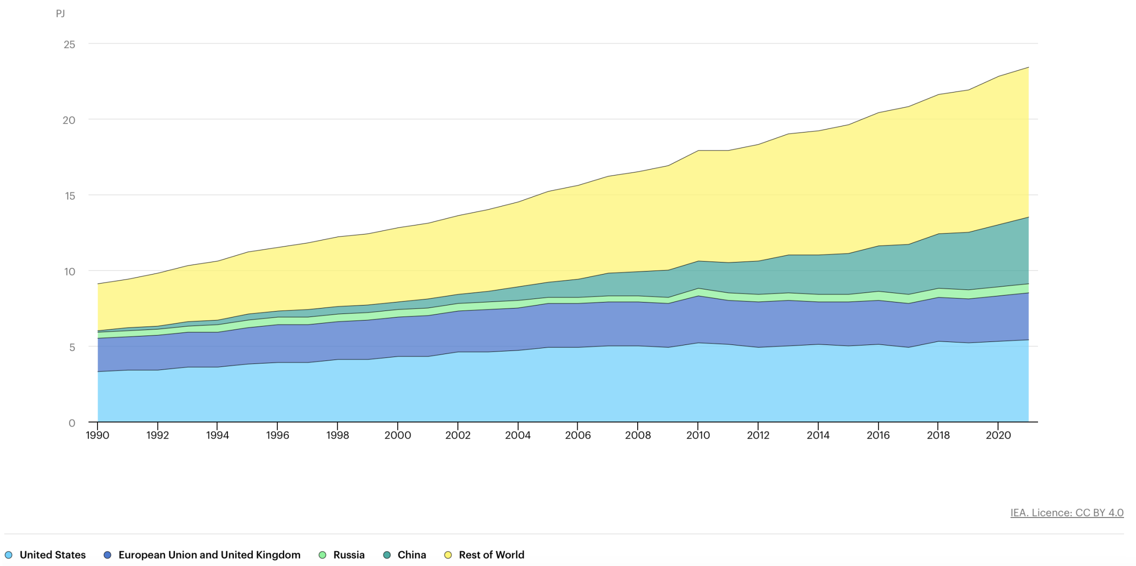


Figure 1.8: Evolution of electricity demand in residential sector, by country and region, 1990-2021. Source: https://www.iea.org.

The first and third points were discussed in Chapter 2 and the second point in Chapter 1.1.

1.2.2 Water & sewage

In Figure 1.9 statistics on water consumption in Europe in various economic sectors are shown. Most water is used in agriculture (see Chapter 4), in the production of electricity and by households (see Chapter 2). The key aspect of reducing water consumption is its tight distribution within the city. Based on data from the European Environment Agency, up to 60% of water can be lost due to leaky pipes (https://www.eea.europa.eu). An opening of just 3 mm causes the loss of 340 liters of water per day. So a key aspect of saving water

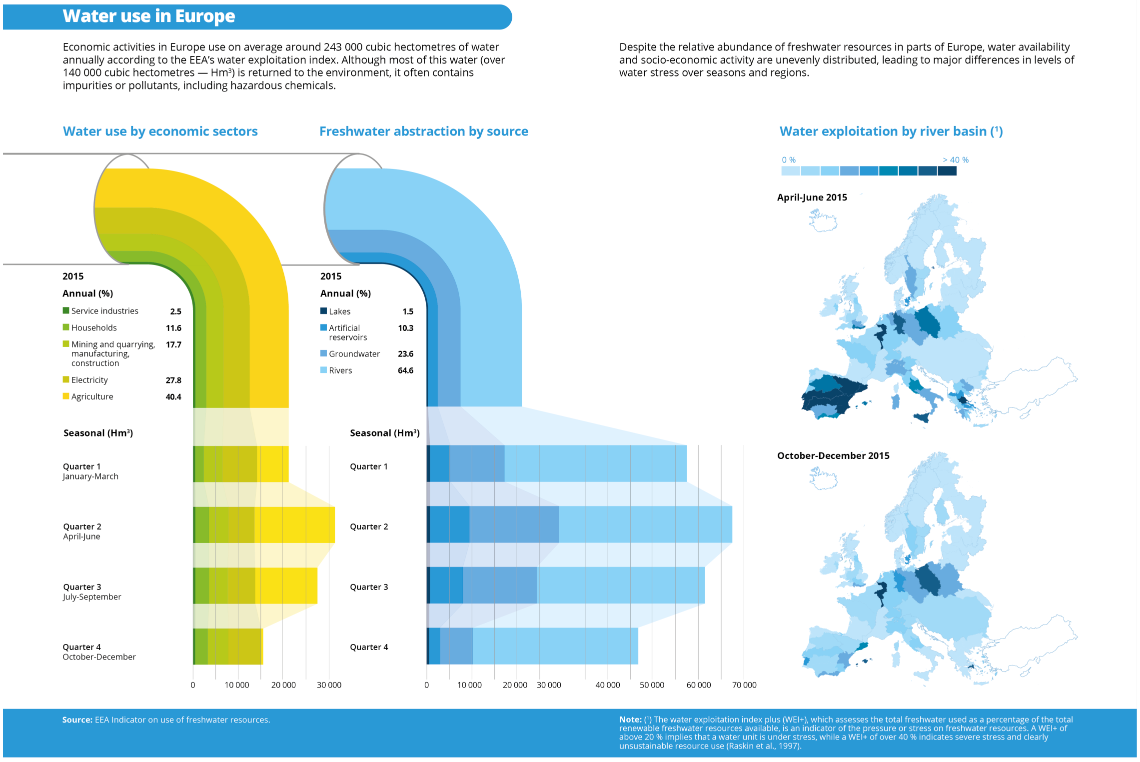


Figure 1.9: Water consumption in Europe. Source: https://www.eea.europa.eu

would be to use water flow sensors on pipes to detect leaks. Such a system could help in efficient monitoring and repairing damages and thus significantly contribute to water loss reduction.

Another key aspect is wastewater treatment. The percentage of connected residential buildings in Europe ranges from 70% to 97%. Modern treatment plants remove contaminants from water quite effectively (except for e.g. microplastics), but the reuse of water from the treatment plant is very low and amounts to only 2.4%. Such water is not suitable for use in the food industry, but it could be used for tasks where water purity is not so crucial, e.g. toilets, car washes, some industries, etc. Internet of Things technology could help in monitoring water quality and efficiency of wastewater treatment.

1.2.3 Waste management

In cities and non-urban areas, effective waste collection is of great importance. The current waste collection system is based on a schedule where a garbage truck collects a given type of waste from a given area on an appropriate day of the week. This approach means that the garbage truck collects waste from garbage bins that are filled to varying degrees, using a lot of fuel to stop at each property in the designated area. The mentioned system can be improved using IoT technology by installing sensors measuring the level of basket filling as shown in Figure 1.10. Based on the readings from the bins, the algorithm can determine the most optimal garbage collection route so as to collect garbage from the most full bins while using the least amount of fuel (see Figure 1.11).

Another waste management problem is recycling. The level of recovered raw materials from garbage varies significantly depending on the country (see Figure 1.12) and is also

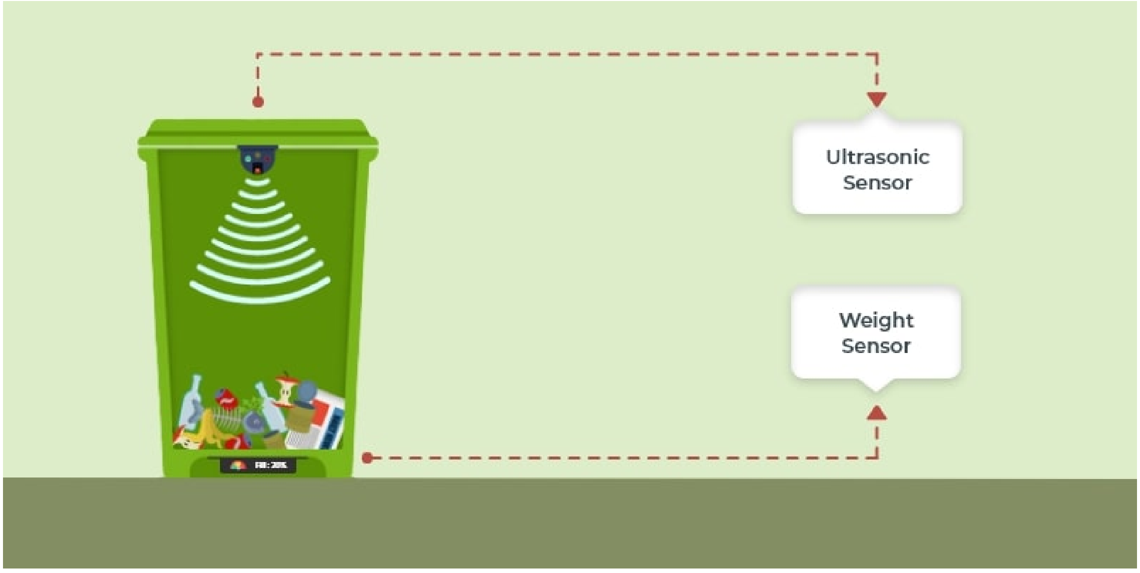


Figure 1.10: The idea of smart waste bins. Source: https://www.excellentwebworld.com

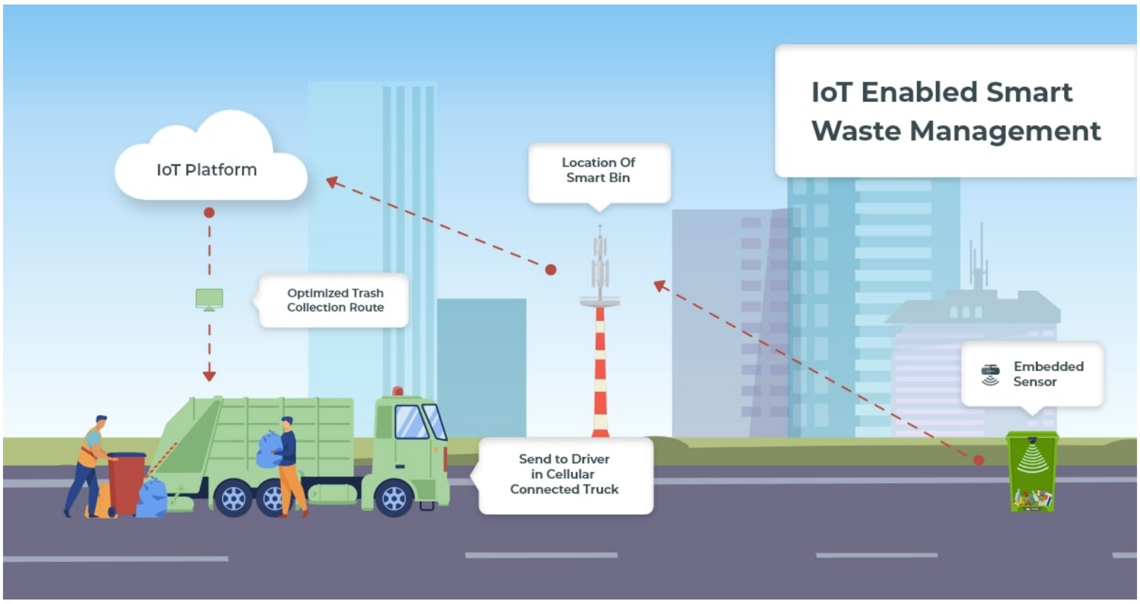


Figure 1.11: The idea of smart waste management system. Source: https://www.excellentwebworld.com

influenced by the correctness of placing given waste in garbage bins. People are often misinformed about where they should throw away a given product, which leads to problems with recovering raw materials. The solution to this problem would be to create waste bins equipped with cameras that, based on the image of the thrown item, would display on the screen where to throw a given product (plastic, paper, glass, mixed waste).

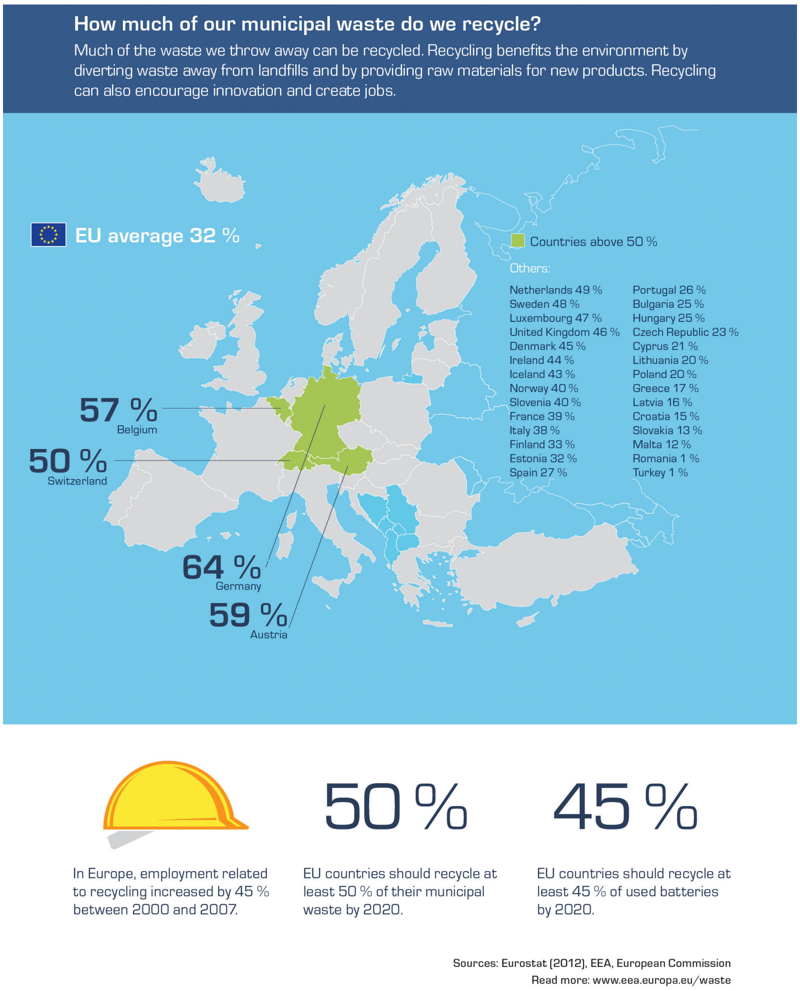
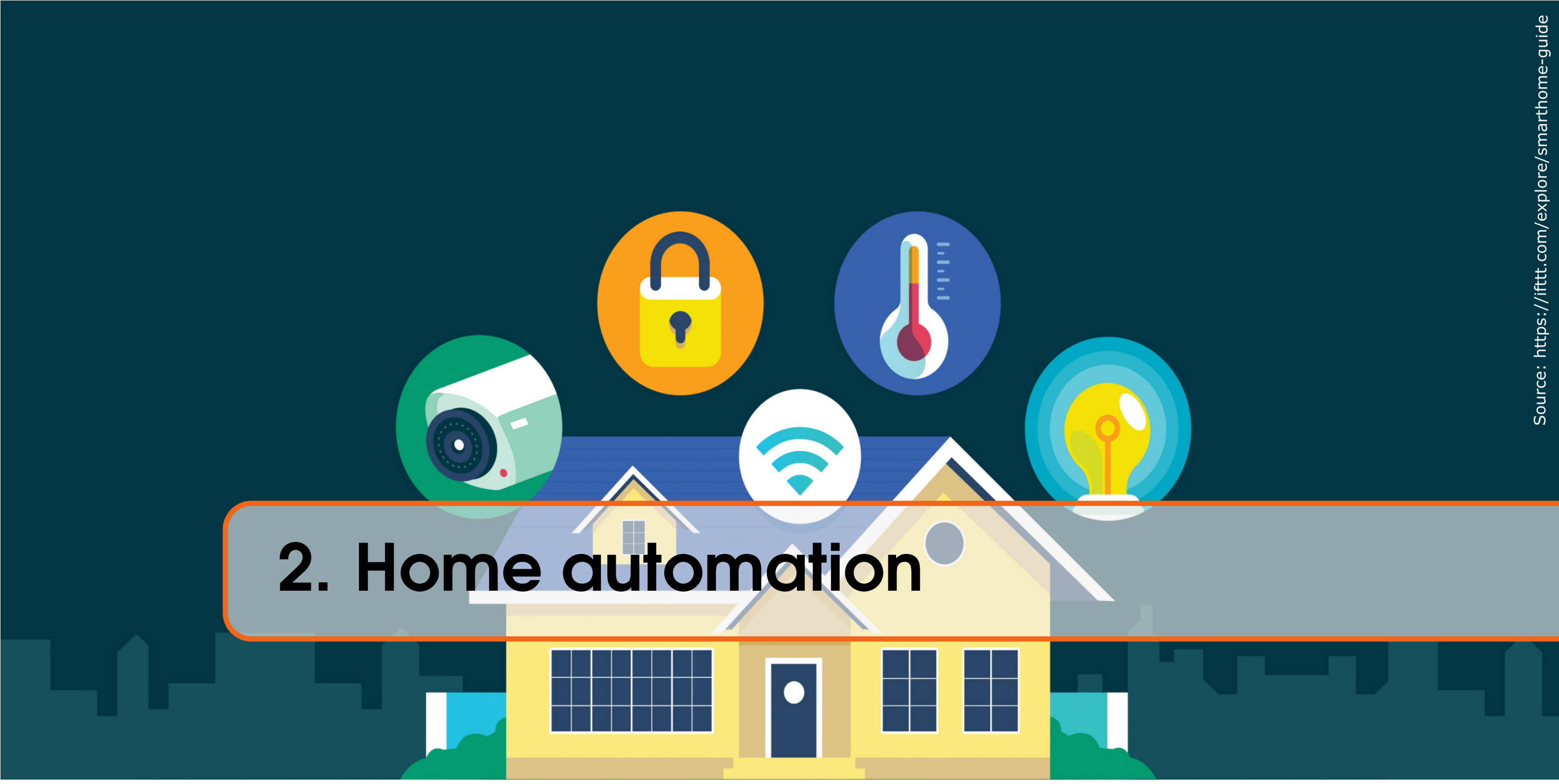


Figure 1.12: The recycling statistics in Europe. Source: https://www.eea.europa.eu

Robots can also help in sorting municipal waste by analyzing garbage poured onto the conveyor belt and catching those that were mistakenly thrown into a given type of waste. In addition, they can help you choose specific products from the pile of garbage (e.g. only batteries).

1.3 Telecommunication systems

An important aspect of the development of IoT is an efficient telecommunication network. However, IoT can also be used for its development, which will enable targeting areas with poor Internet coverage. For this purpose, it would be enough to create drones that would analyze network parameters in a given area, creating a map showing where there are areas with poor Internet coverage. In this way, telecommunication companies could more consciously develop their infrastructure, contributing to better customer satisfaction.



Source: https://ifttt.com/explore/smarthome-guide

2. Home automation

Smart solutions for homes are becoming more and more popular. They help not only to increase comfort and safety, but also to save money by reducing the consumption of, for example, electricity. In this chapter, we will present selected smart solutions and ideas based on IoT.

In Figure 2.1, the average electricity consumption in homes in Europe is presented.

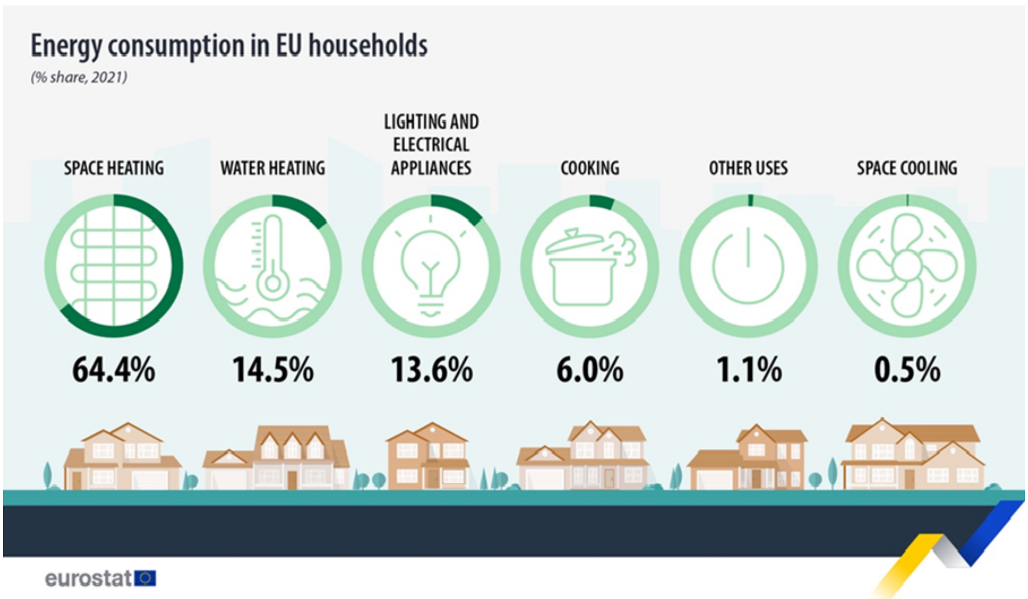


Figure 2.1: Energy consumption for an average household in Europe. Source: https://ec.europa.eu.

Below are IoT ideas that can help you save electricity:

- home heating - depending on the heat source used (solid fuel furnace, gas furnace, heat pumps), electricity consumption will vary. Nevertheless, a smart home should use as little resources as possible, such as eco-pea coal, pellets or electricity. To reduce the consumption of resources, combustion in furnaces or the heat pump's operating power should be adjusted to weather conditions. For this purpose, a simple

IoT system with a weather sensor mounted outside the house and temperature sensors installed indoors is enough. Then you can select the operating parameters of the heat source to ensure a comfortable temperature inside the house with the lowest possible consumption of raw materials and electricity.

- water heating - another problem is water heating, for which we use on average about 14% of electricity. Very often, water is heated when no one is at home, which is economically unjustified. Here, an IoT system based on water flow sensors installed in taps can be used. The system would analyze at what times water is used in the house and adapt water heating to the needs of residents.
- lighting - to reduce lighting costs, motion and darkening sensors should be used, which would adjust the lighting intensity to current weather conditions and the needs of tenants.
- air conditioning - reducing air conditioning costs is analogous to reducing home heating costs. Therefore, weather sensors installed outside the house and temperature sensors in winter can help adjust the heating to the climatic conditions and in summer, adjust the air conditioning to the needs of tenants. This way, one system can be used for two devices.

Another important aspect is the reduction of water consumption by households. In Figure 2.2 statistics of water consumption in homes in Europe depending on the performed activity are presented.

Figure 2.2: Water usage for an average household. Source: https://www.mynicehome.gov.sg.

In most of them, it is enough to change habits, but some problems can be helped by IoT technology, e.g.

- laundry - to reduce water consumption, all you need to do is install weight sensors in the washing machines. After weighing the clothes, system would adjust the amount of water to the weight of clothes and also motivate the user to add more clothes to use the washing machine as full as possible, thus also reducing electricity consumption.
- watering gardens - watering plants in the garden is crucial when there is a major drought. For this purpose, it would be necessary to use an IoT system based on

weather and soil moisture sensors. In this way, the system would control the watering of plants to ensure optimal soil moisture and that the system would only operate when necessary (strongly sunny days without rain).

In the face of the growing number of inhabitants of the Earth, it is important to save food and avoid wasting it. In Figure 2.3, statistics on food waste per capita in Europe were presented. Most food is wasted at home through irrational purchases and throwing away products bought and not consumed on time. To reduce this phenomenon, an IoT system can be developed that will monitor the composition of the refrigerator through cameras that recognize what has been put into and what has been taken out of the refrigerator. In the application, the user would see what he has at home and in what quantity, which would contribute to more conscious purchases of products in the store. The application could also inform you which products have the shortest date to consume them first. In a more extensive version of the application, it would be possible to propose ready-made recipes for using products with the shortest expiration date based on the list of products that are in the fridge.

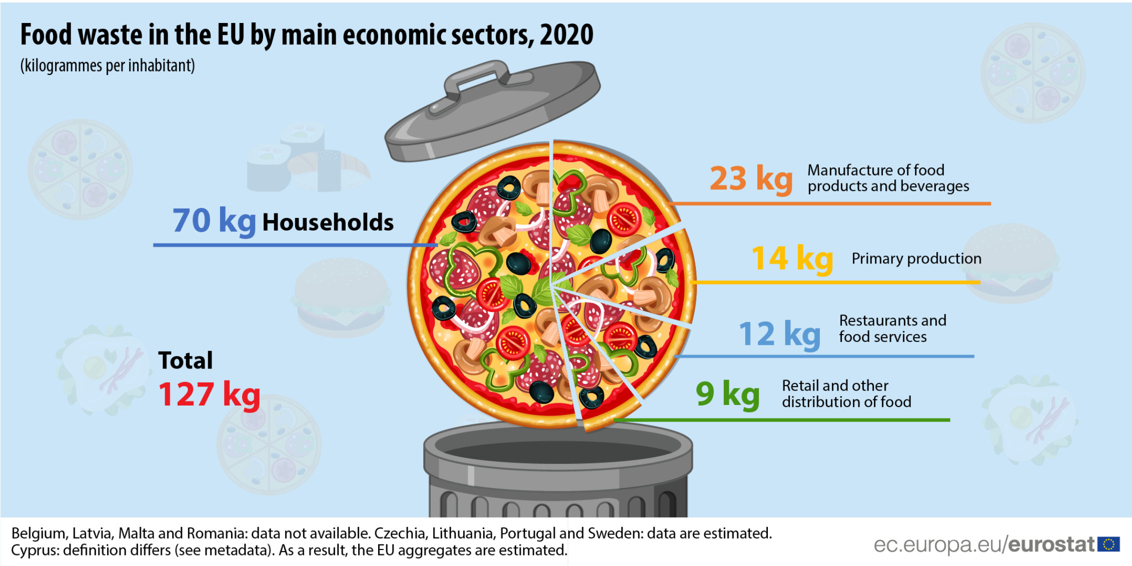


Figure 2.3: The statistics of food waste per inhabitant in Europe. Source: https://ec.europa.eu.

IoT systems can also be used to improve the comfort of residents, e.g. by adjusting the conditions in the house to optimal ones. An example of such a solution could be a system that monitors the air quality in the house and, based on its parameters, activates air humidifiers or an air purifier to remove dust. Moreover, the system could measure whether carbon monoxide is released in the rooms or whether there is a fire and inform the appropriate services about the threat to life.

The last proposed IoT system for homes could be a monitoring system equipped with cameras that would detect potential intrusions and inform the user about the threat.

2.1 Smart Home automation for senior citizens

Advancements in technology have greatly simplified our daily lives, offering an array of tools and services to streamline various aspects of our work and household management

[1]. While smart home automation is not a new concept and has been aiding countless individuals in simplifying household processes for some time [2], it's essential to assess seniors' readiness to adopt, understand, and potentially even develop such solutions. This is particularly pertinent given the challenge many seniors face in finding fulfilment and purpose post-retirement, often experiencing feelings of isolation and disconnection [3].

Research indicates that seniors, especially post-retirement, may struggle with feelings of isolation and unfulfillment, making it crucial to explore activities and skills that stimulate their interests, engage them in hands-on tasks, and enhance critical thinking abilities [4]. Embracing new hobbies or learning new skills, especially those involving practical application, has been shown to be particularly beneficial for seniors [5].

While the connection between smart home technology and the needs of senior citizens is evident, there remains a gap in adoption due to a lack of familiarity and skills among many in this demographic. Seniors have specific household needs related to safety, security, comfort, and overall control, which can be addressed through smart home solutions. Additionally, physical or mental limitations may hinder their ability to manage daily tasks independently, further emphasizing the importance of accessible and intuitive technology [6].

Understanding the functionalities and applications of smart home solutions can be challenging for both younger and older seniors. However, a wide range of products and services exists to cater to various needs, such as home security, reminders, and environmental control. Moreover, seniors can create custom home automation solutions tailored to their specific requirements using simple electronics and sensors such as smart weather reporting systems, smart emergency systems, smart garage door systems, smart doorbell systems, and smart thermostat systems [7].

Beyond simplifying daily tasks, IoT solutions for smart homes also offer opportunities for preventive maintenance [8]. For instance, appliances equipped with sensors can alert owners to maintenance needs, minimizing the risk of breakdowns and reducing the inconvenience of waiting for repairs, particularly in remote areas. Similarly, sensors can detect issues and provide guidance on resolving them, enhancing the overall reliability and longevity of household appliances.

3. Health monitoring

The key challenge of the 21st century will be to provide adequate medical care to an increasing population. Based on data from Eurostat (see Figure 3.2), society in Europe is aging and the median age is increasing (currently about 44 years).

At the same time, statistics show that fewer children are still being born than should be in order to maintain a constant number of people at pre-working and working age. Current statistics show that on average 1.5 children are born per woman (see Figure 3.1) and every tenth child is born prematurely. With such indicators, the key aspect will be to ensure the highest possible survival rate among the children born.

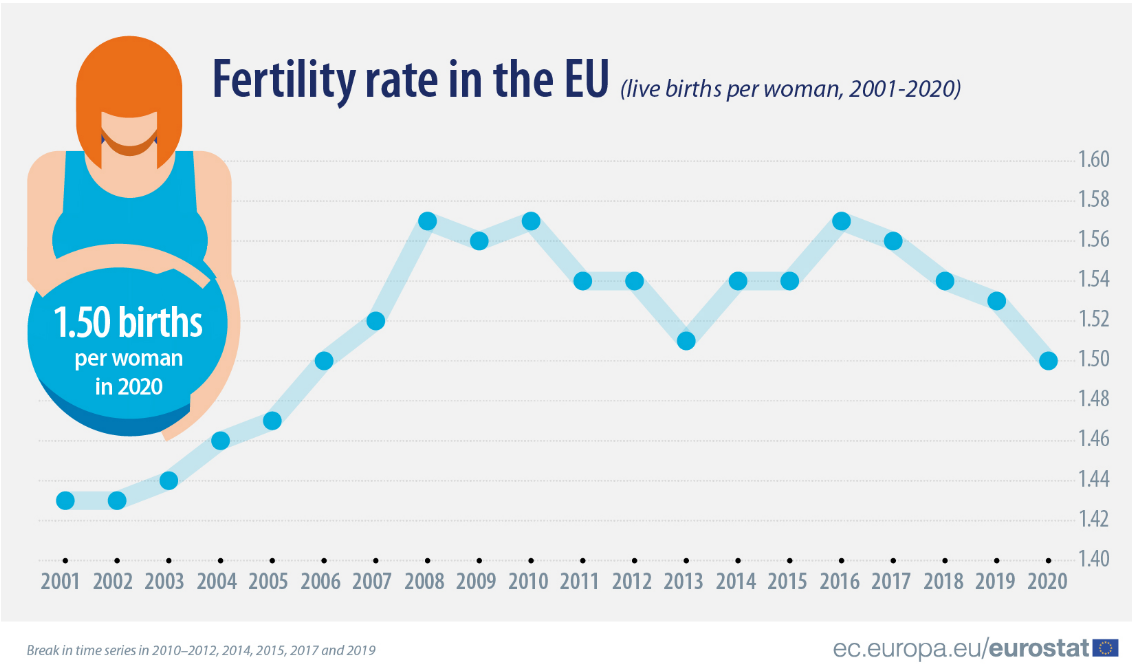


Figure 3.1: Fertility rate in the European Union in 2001-2020. Source: https://ec.europa.eu/eurostat/

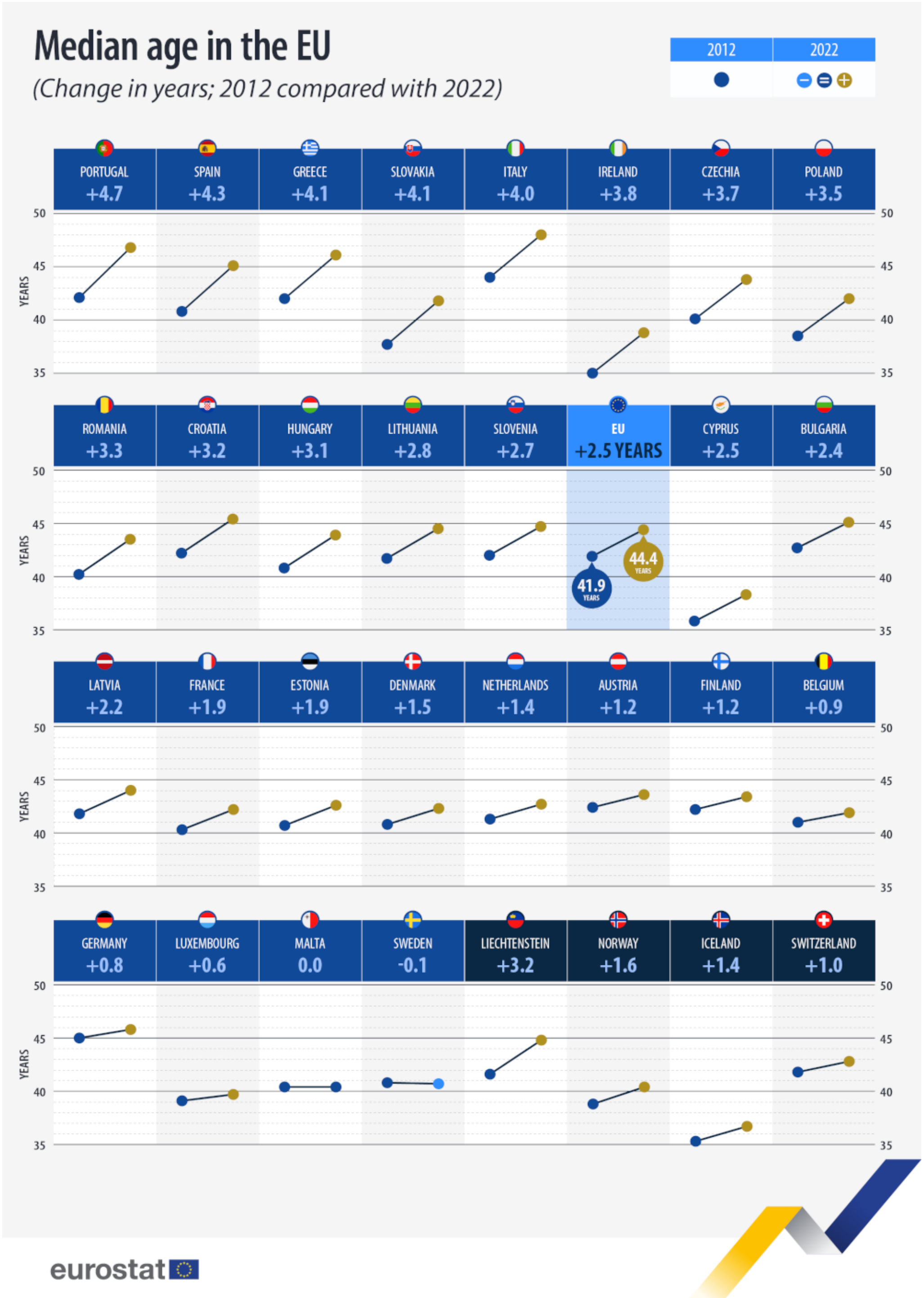


Figure 3.2: Median age in the European Union. Source: https://ec.europa.eu/eurostat/

Currently, the greatest challenge in neonatal care are prematurely born children. According to statistics, approximately 50% of deaths among newborns occur in children born prematurely (see Figure 3.3). To ensure the highest possible survival rate of newborns, great emphasis should be placed on the development of neonatology and monitoring of newborn health parameters. IoT technology can help monitor key health parameters of newborns, such as: proper weight gain (body weight measurements on scales), monitoring of proper breathing (apnea detection mattresses), heart rate and saturation measurements, and data acquisition from mobile stethoscopes. The mentioned devices already exist on the market, but they are separated products that should be integrated, processed and analyzed on an ongoing basis and made available not only to parents but also to midwives and neonatologists who take care of the child and ensure its proper development.

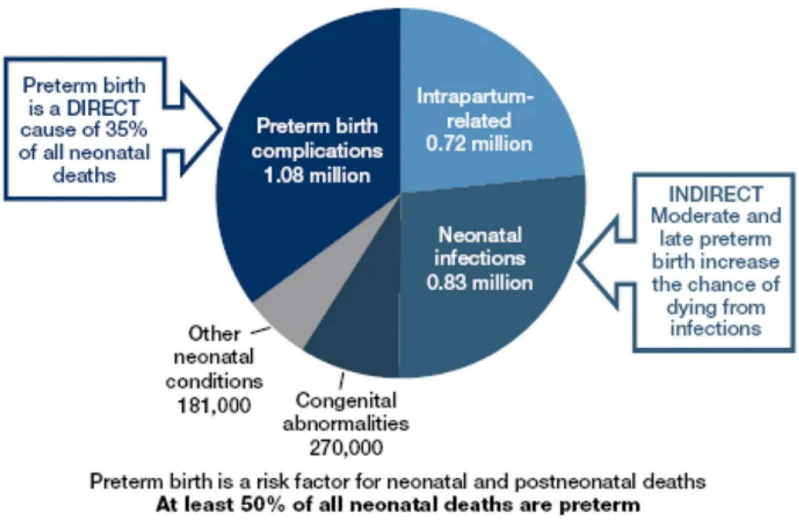


Figure 3.3: Estimated distribution of causes of 3.1 million neonatal deaths in 193 countries in 2010. Source: https://reproductive-health-journal.biomedcentral.com.

The aging of society necessitates the development of the geriatrics. Caring for people in post-working age is quite difficult because patients not always are able to properly describe their symptoms. Hence, a key aspect in the care of the elderly is monitoring their health, in particular parameters such as: pressure, heart rate, sugar level and saturation. IoT technology can also help in monitoring these parameters, which, based on readings from sensors, would provide information to the closest family caring for the elderly person and to the doctor.

Mortality statistics for specific diseases in Europe indicate that most people die from circulatory system diseases (see Figure 3.4). Therefore, measuring blood pressure and heart rate as well as analyzing ECG records on an ongoing basis is crucial not only for older people but also for young people who are also susceptible to cardiovascular diseases. Often, these diseases do not cause any symptoms, and measuring devices could prevent the development of cardiovascular diseases.

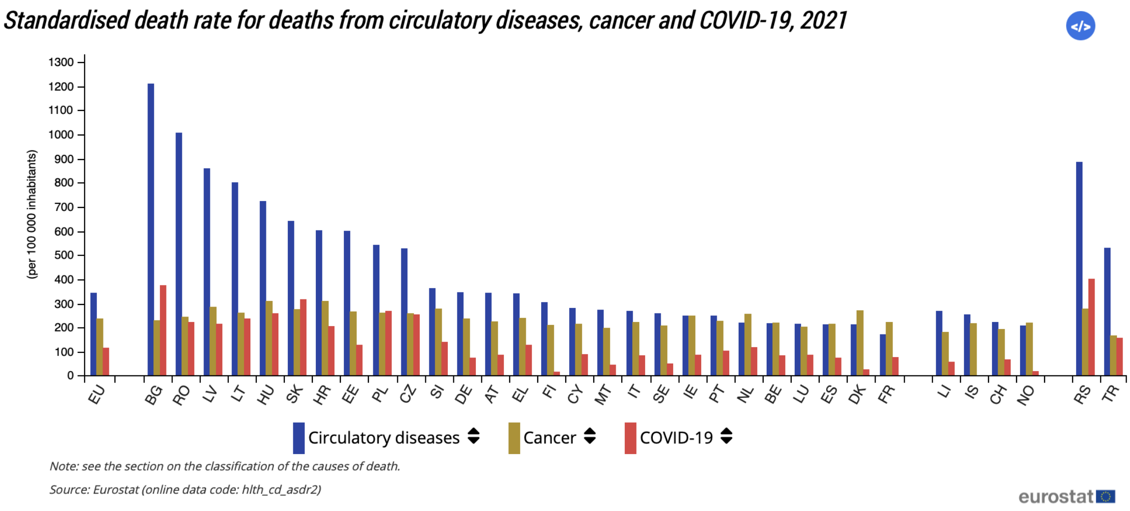


Figure 3.4: Cause of death in Europe. Source: https://ec.europa.eu.

4. Environmental protection

This chapter includes selected aspects of environmental protection in which IoT technology can help. One of them is the control and improvement of air quality. In Figure 4.1, air pollution in Europe with particles smaller than 2.5 μg was presented.

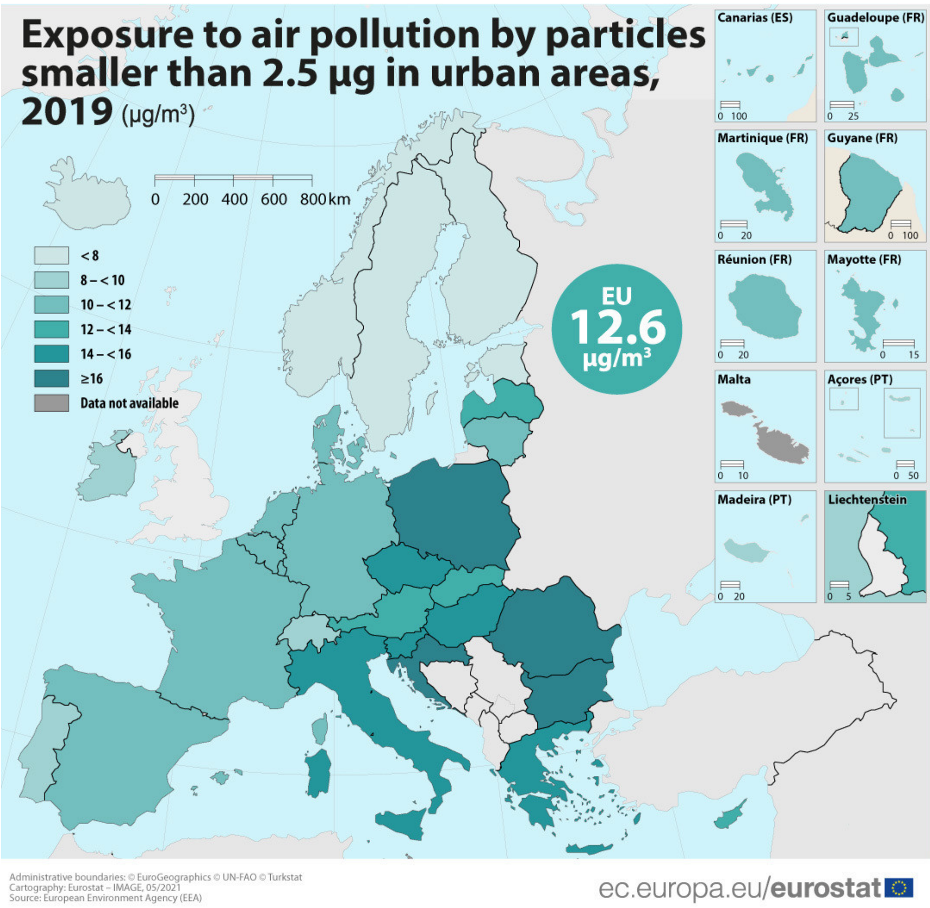


Figure 4.1: Exposure to air pollution by particles smaller than 1.5 μg in urban areas in 2019. Source: https://www.weforum.org.

Based on the available data, it can be seen that the greatest air pollution problem occurs in Central and Eastern Europe, where the methods of heating in houses have a significant impact on air quality (see Figure 4.2).

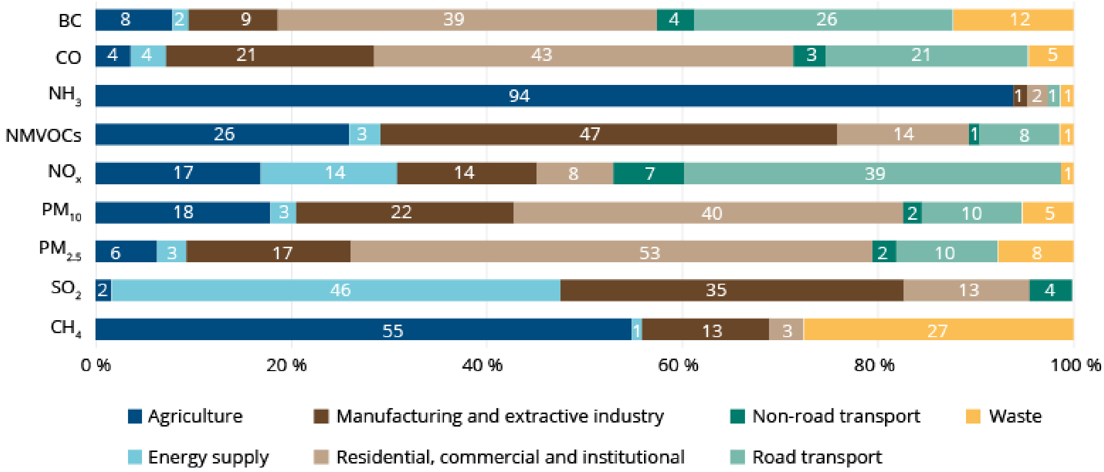


Figure 4.2: Contribution to EU-27 emissions of BC (Black Carbon), CO, NH_3, NMVOCs, NO_X, primary PM_{10}, primary $PM_{2.5}$, SO_2 and CH_4 from the main source sectors in 2019. Source: https://www.eea.europa.eu

The dominant source of heating in houses is still solid fuel stoves, which, depending on the technology, can emit significant amounts of dust into the atmosphere (e.g. black carbon). To reduce the problem of poor air quality, which contributes to the death of 7 million people annually in the world, we should focus on monitoring of air quality and developing a strategy to eliminate the problem in the most polluted regions of Europe. IoT technology can be used to create numerous air quality monitoring stations as well as to control chimneys by installing sensors on drones (see Figure 4.3).

Figure 4.3: Drones, which are used to control chimneys. Source: https://strefamiast.pl/

IoT technology can also be used to monitor the condition of rivers in Europe. According to Figure 4.4, there are still many flood events in Europe, which also causes flooding of inhabited areas. Based on water level sensors, it would be possible to inform the authorities where a flood may occur in order to protect the area from flooding and to evacuate only those residents who are actually in the flood risk zone. Additionally, IoT technology can be used to monitor water quality and develop strategies to improve water in areas where it does not meet quality requirements.

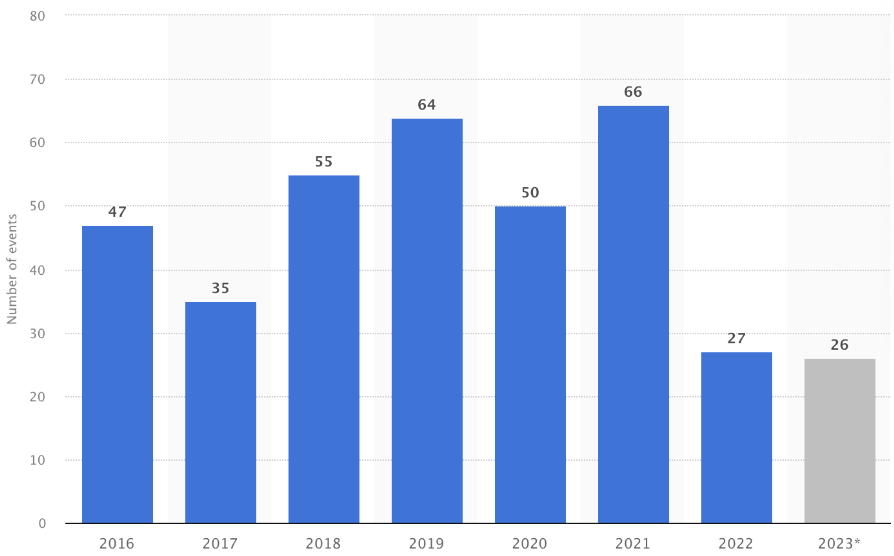


Figure 4.4: Number of reported flood events in Europe from 2016 to 2023. Source: https://www.statista.com

A key aspect related to environmental protection is rational agriculture. IoT technology can help to control soil quality, irrigation and crop quality in order to sensibly manage watering, fertilization and use of plant protection products against pests.

IoT technology can also be used to control endangered species by monitoring these species, their habits and where they live. Based on this information, ways to protect these species can be determined to ensure their growth.

4.1 IoT solutions for wildfires

Wildfires are a growing phenomenon with global implications. Severe and widespread fires have caused untold damage to the ecosystem [9]. The negative impacts of wildfires are enormous. According to the Western Fire Chiefs Association, the top 5 negative impacts concern global pollution (in terms of air and water quality), health (especially for respiratory and cardiovascular system), property (in terms of loss of property, agricultural crops and other kind of resources, as well as domestic animals), ecology (with a major impact on animal and plant life), and logistics (in terms of major problems with power and water supply and communications) [10]. Based on Copernicus Atmosphere Monitoring Service (CAMS) data, 2023 was “a year of intense global wildfire activity” [11]. According to this data, carbon emissions from wildfires in 2023 were approximately 2.170 megatons. Canadian wildfires (responsible for 22% of CO_2 emissions) burned 18 million hectares of land while the smoke and particles emitted were carried as far as Europe. These emissions were 5 times higher than the average emissions over the last 20 years, with a general impact even on US farms [11]. In Greece the wildfires were the worst the country has seen in 20 years [11], with the fire in the Dadia National Park (in the region of Thrace) being the biggest ever in Europe, burning over 810 sq km, leading to huge losses of wildlife and human life [11, 12]. The vast majority of forest fires (75%) are caused by people, either intentionally or unintentionally [13]. In addition to the human factor, climate change is having a significant impact, extending the periods during which wildfires can occur and creating the conditions (warmer temperatures, drier weather etc.) for more extreme wildfires [9, 13].

In this direction, IoT can make a significant contribution, especially in the way that emergency services organizations operate. Through devices such as smoke detectors, motion sensors, cameras and alarms, IoT can promote methods of monitoring data, detecting fire as it is developing and (through the use of Information Systems) informing firefighters to respond quickly, thus preventing the development of an extreme fire [14]. In addition to detecting fires, IoT systems can provide useful information about weather conditions and traffic, thus helping firefighters make better decisions about how to approach a fire [14]. Beyond wildfires, IoT systems can be used in buildings to detect fires in real time and notify both residents (to evacuate the building) and firefighters to respond as quickly as possible [15]. Additionally, IoT systems can provide information on the structural integrity of a building in flames, helping firefighters to develop a better and safer response plan [14]. IoT devices can also monitor the condition of a piece of equipment and inform the emergency services when maintenance work needs to be carried out [16]. IoT systems can therefore reduce response times, while the data collected can be used to improve training, equipment and firefighting strategies.

4.2 IoT solution for water conservation in crops

The rising population of the planet demands an increase in agricultural production. In fact, by the year 2050, it is expected that an increase by 70% will be required, to keep up with the forecast of (almost) 10 billion people on the planet [17]. This, in itself, requires even larger amounts of fresh water, with an expected increase by more than 50% by 2050. At the same time, fresh water remains a commodity for many parts of the world, with only 0.003% of the available water on the planet being suitable for drinking, hygiene, agriculture and industry [18].

EU recognizes the need to conserve fresh water, and to protect agriculture, developing a common agricultural policy <<to help protect the role of water for food, farming and the environment>> [19]. In EU countries, especially southern Europe, where rain usually only happens during winter, water becomes an even tighter resource. Therefore, conservation of the water is of paramount importance. An increase in water usage over the past 50 years has lead to a decrease by 24% of renewable freshwater resources. This increase of consumption is directly related to more people moving to cities and towns in the past 50 years [20].

The rising population and the increase requirements in agriculture, requires the EU to encourage better use of water resources. One way of ensuring optimum use of water is to enforce pricing policies and regulations that give incentives to farmers to make better use of available resources. However, these have not necessarily had the desired effect [21] since -in several cases- local authorities rarely impose penalties or sanctions.

It is clear that, through sanctions and penalties, it is not possible to achieve the desired result of preserving water and optimising its use, especially in agriculture. However, through the use of technology and other means, it is possible to achieve this. One good example is Spain, whose government used several methods, including technological means to adjust water usage, including storing of rainwater, and has managed to improve the production of crops, while at the same time reducing the waste of water [22]. This has been achieved by (also) implementing -in most farmlands- advanced irrigation technologies and automation, including remote control and soil moisture monitoring.

Use of IoT for water efficient irrigation:

In places with scarce natural (fresh water) sources, such as islands (ie Malta, Cyprus), available water for crops by natural means (ie rain) is dependent on specific period of the year (for example, during winter with ample rainfall.This, of course, is a wider problem faced by many countries in other parts of the world (for example, India). In cases where IoT technology has been used to optimise water usage, the results have been encouraging. For example, the use of IoT devices to control irrigation, can provide real-time data on soil conditions, offer localised weather forecasts, and provide an estimate on water loss due to evaporation [23]. In such cases, where there is ample rainfall, any system (automated or not) might not be required to provide additional water. As such, IoT solutions can be used to optimise the delivery of water.

Additionally the use of IoT can help preserve crops from possible damage due to frost. Watering plants is a way to prevent frost damage [24].

As such, it is necessary to make the best use of the amount of water used in plantations, based on the specific weather conditions, something that can be unpredictable, leading to an increase in the number of personnel required. Even though this might seem that it creates more jobs, in fact it might lead to (a) an increase in production costs - leading to an increase in the cost of the actual products and (b) the use of more water for plants than really needed. Especially in remote areas, it is not often possible to find proper personnel, and in some special cases (ie frost in the middle of the night) not possible to have them available at all times on the spot.

An IoT solution that can sense the humidity in both the soil and in the atmosphere, can lead to an optimisation of the use of water for the crops. In such a case (for example, if ample rainfall was experienced in the same or previous day or days), our system might "select" not to provide additional water. Furthermore, if the sensors identify the formation of frost to the crops, it might be possible to administer water at regular intervals, so that the plants will be protected by its harmful effect.

Additionally, water tanks can be used, connected to a system based on IoT devices, to gather rainwater, and to provide farmers with data on the quantity and quality of available water. The above proposal can be created, as a small "proof of concept" project, in secondary schools.

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IoT
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