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The Impact of Telemedicine on Reducing Carbon Footprint

Abstract

Objectives: The purpose of this paper is to explore the possibilities of reducing the carbon footprint in the Polish health care, focusing on the way by which medical service professionals use communication technology to provide information for diagnosis, treatment, prevention, and consultation, or to obtain medical knowledge for the improvement of the patient's health.

Research Design & Methods: Based on data on the number of home visits and its connection with the number of teleconsultations in the surveyed region, the possibility of reducing the carbon footprint in this area was analysed. In addition, the population living in each region of the country was considered. Values were calculated for the years 2020 and 2021.

Findings: The correlation between the topic of decarbonisation and telemedicine (i.e. a form of medical and health care delivery that combines elements of telecommunications, information technology, and medicine). is quite obvious. A rather clear scenario confirming the positive impact of telemedicine on the environment is the minimisation of the need to visit medical centres by patients to obtain basic medical services (consultation with a clinician, prescription, etc.)

Implications / Recommendations: The possibilities that telemedicine brings to the health care field are immense, and the only limitation we currently face is the speed at which this technology is adopted in everyday realities. We are currently facing a paradigm shift in the perception of medical services from the traditional approach (one in which the patient had to reach a clinician in person to receive medical services) to the innovative one (supported by various technologies that make it possible to provide medical services remotely), which improves the quality of health care services. The COVID-19 pandemic has proven that some services can be delivered differently. The use of innovative methods of diagnostics and patient care using IoMT-related solutions contributes to reducing the environmental impact of the carbon footprint that is generated by the health care field.

Contribution / Value Added: Climate change has a significant impact on human health. Obviously, climate change is not the only factor affecting human health. In the article, we deliberately narrow the domain of analysis to this factor and will not consider a broader scope. In order to demonstrate the commitment to reducing their environmental impact, organisations and companies more often measure and report carbon footprint. Moreover, the pandemic crisis situation, i.e. COVID-19, has brought rapid changes in clinical practice. The huge potential of using the available technology – e.g. the IoMT (Internet of Medical Things) – to support the health care field has been recognised. This technology is one of the important elements of telemedicine.

Keywords: decarbonisation, telemedicine, carbon footprint in health care

Article classification: research article

JEL classification: Q560, I180, O330

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Introduction

Health care in Poland is publicly financed and provides access to medical services for the country's entire population. The health care system in Poland is based on health insurance, and funding is provided through the National Health Service (NHS) (NFZ, 2023). The health care system in Poland consists of two sectors – public and private. The public sector consists of public hospitals, clinics, and outpatient clinics, which are financed by the state and the insured. The private sector includes private clinics and hospitals, which can be accessed directly or through private insurance. There are many types of specialised medical services, such as treatment, diagnosis, rehabilitation, long-term care, and palliative care. Health care in Poland is also based on the primary care system, which provides access to primary care through family doctors and community nurses. However, Poland's health care system faces many challenges, such as the shortage of medical staff, inequality in access to medical services in rural areas, and low salaries for medical staff. As a result, the government is taking steps to modernise and improve Poland's health care system. Health care management optimisation is the process of improving operations to enhance the efficiency and quality of medical care while increasing savings. Here are some ways to optimise health care management (Wickramasinghe, 2020):

- the application of information technology – information technology, such as medical data management information systems, can help improve the efficiency and accuracy of medical data management as well as facilitate the management of financial and administrative data;
- efficient resource management – optimal management of resources, such as people, medical equipment, drugs, materials and services, can help minimise costs while increasing the quality of medical services;
- improving medical processes – understanding medical processes and using best practices can help reduce medical errors and improve patient outcomes;
- implementing standards and guidelines – implementing standards and guidelines for medical practices can help increase the quality of medical care, minimise the risk of errors, and increase patient safety;
- cooperation and coordination across sectors – collaboration and coordination between sectors, such as health care, long-term care, and social care, can help ensure consistent care for patients and minimise costs;
- continuous improvement – continuous improvement of medical processes and practices is key to ensuring continuous improvement in the efficiency and quality of health care.

Optimising healthcare management is a multi-step process that requires the involvement of both government authorities and health care professionals. An effective use of information technology, the improvement of medical processes, and continuous improvement are key to providing effective medical care while minimising costs and increasing quality.

The term 'Internet of Things' (IoT) was first used by British entrepreneur and startup founder Kevin Ashton (ETHW, 2023) in 1999, during a presentation to Procter & Gamble. IoT is a technology that allows various electronic devices to be connected to each other via the Internet, enabling real-time data transmission and collection.

The 'Internet of Medical Things' (IoMT) in healthcare is a way to describe the interconnected infrastructure of medical devices that doctors, patients, and consumers rely on (Kim et al., 2022). Surgical robots and smart monitoring equipment in hospitals are certainly prime examples of IoMT, but so are everyday fitness trackers, smart home monitoring devices, etc. In medicine, the IoMT has many applications that contribute to improving the quality of health care and resource efficiency. The IoMT connects people (patients, caregivers, and clinicians), data (patient data or performance data), processes (care delivery and patient support), and tools (connected medical devices and mobile apps) to deliver better patient outcomes (Deloitte Centre for Health Solutions, 2018).

The primary difference between the IoT and the IoMT is the reliability of the devices as well as the issue of data security.

One of the most important applications of the IoMT in medicine is monitoring patients' health remotely. This allows doctors to track a patient's vital signs, such as blood pressure, heart rate, blood sugar, body temperature, and more, even when the patient is at home. In this way, health problems can be detected earlier and interventions can be made faster, resulting in improved treatment outcomes. The IoMT can also help optimise resource management in medical facilities. By using smart systems to monitor and control the consumption of resources such as water, energy, medical equipment, as well as disinfectants and other materials, costs can be saved while increasing the safety of patients and medical staff. Another application of the IoT in medicine is telemedicine, or the provision of healthcare services via the Internet. This allows patients to have faster and easier access to health care, while doctors can consult with other specialists, issue e-prescriptions, and conduct medical appointments online. Ultimately, the IoMT can help improve patient safety and the quality of medical care. Through the use of intelligent monitoring and alerting systems, potential health risks to patients, such as inappropriate medication dosages or the risk of hospital-acquired infections, can be detected more quickly. The use of the IoT in medicine has many benefits, such as increasing resource efficiency, improving the quality of health care, and enhancing patient safety.

Carbon footprint

What is a carbon footprint?

A carbon footprint (El Geneidy et al., 2021) is a measure of the amount of greenhouse gases, mainly carbon dioxide (CO_2), emitted into the atmosphere by a specific product, service, or process. It is a proxy for the environmental impact of a particular product, service, or process, particularly on climate change. The carbon footprint takes into account the greenhouse gas emissions over the entire life cycle of a product or service, from raw material extraction and production, to transportation, use, and disposal or recycling. This means that not only direct emissions related to production, but also indirect emissions related to electricity consumption, transportation or waste management are taken into account in calculating the carbon footprint. Determining the carbon footprint is important from the point of view of environmental protection and the fight against climate change, as it allows the identification of the largest sources of greenhouse gas emissions and the identification of measures to reduce them. The health care carbon footprint refers to the amount of greenhouse gases emitted by medical sector activities, including hospitals, clinics, laboratories, as well as by the production and distribution of medicines and medical equipment. According to a report by the Global Climate and Health Alliance, the health care sector is responsible for about 4.4% of global greenhouse gas emissions (Health Care Without Harm & Arup, 2019). The largest sources of emissions in health care include electricity, which is used heavily in hospitals and clinics, water consumption, medical transportation, and the use of medical equipment such as X-ray machines and CT scanners. However, many hospitals and clinics around the world are taking steps to reduce their carbon footprint by investing in green technologies and renewable energy, reducing energy and water consumption, using greener modes of transportation, as well as reducing medical waste (García-Sanz-Calcedo, 2014). Reducing health care's carbon footprint will not only help protect the environment and combat climate change, but will also save money by reducing costs related to electricity, water, and waste disposal. At this point, it is worth mentioning that despite the fact that telemedicine does not play a key role in reducing the carbon footprint in the area of health care at the moment, there are several indications that this role may change dramatically in the future, taking into account several important arguments:

- Incremental Impact – while it is true that electricity, water, and medical equipment consume significant amounts of energy, telemedicine could still have an additive, positive impact on reducing a health care system's carbon footprint. Small increments, when amplified over large systems and periods, can produce meaningful changes.
- Indirect Reductions – telemedicine can lead to reduced patient and provider commuting, which, in turn, cuts down on emissions from transportation. When considered at scale, this could have a non-trivial effect. Moreover, if telemedicine can effectively deal with simpler cases online, it might lead to less frequent use of energy-intensive medical equipment and in-person resources for those cases, thereby indirectly contributing to decarbonisation.
- Future Scalability – as telemedicine technology improves, we may find ways to make it even more energy-efficient. Additionally, if telemedicine can take on a more significant role in health care delivery, including more complicated consults or even remote surgeries via robotics, the energy savings could be more substantial.
- Synergy with Renewable Energy – as health care systems increasingly adopt renewable energy sources, the carbon footprint of the electricity used for telemedicine could decrease, thereby enhancing its role in decarbonisation.
- Holistic View of Healthcare Emissions – decarbonisation is a complex problem requiring multi-faceted solutions. While focusing on the largest emission sources is crucial, a comprehensive strategy would also consider smaller contributors that could add up to a significant impact.
- Changing Landscape – the health care landscape is continually evolving, especially in the context of public health crises such as pandemics, where telemedicine has demonstrated its value. In such scenarios, the role of telemedicine and its potential impact on decarbonisation could be far more significant than in 'business-as-usual' conditions.

For these reasons, although telemedicine's contribution to reducing carbon footprint might not be 'statistically significant' at the moment when compared to the major sources of health care emissions, its potential cumulative benefits should not be underestimated. The paper aims to shed light on these benefits, thus contributing to the wider discourse on health care decarbonisation.

What is telemedicine?

According to the definition of the American Telemedicine Association (ATA), telemedicine is a form of medical information exchange at a distance through electronic communication to improve a patient's health (Miller, 2020). In contrast, the World Health Organization (WHO) states that telemedicine is the provision of medical services by professionals, where distance is a major factor, using communication technologies to exchange relevant information for diagnosis, treatment, prevention, consultation, or obtaining medical knowledge for the improvement of the patient's health (WHO Group Consultation on Health Telematics, 1998). Telemedicine (Szpor et al.,

2019) is a medical field that uses information and communication technologies (ICTs) to provide remote medical services. It involves the use of advanced communication technologies such as teleconferencing, mobile applications, online consultations, and health monitoring systems to allow patients to remotely access medical services and medical consultations as well as diagnose diseases, prescriptions, etc. Telemedicine can be used to provide remote medical assistance to patients who live in remote regions where access to traditional medical care is limited or difficult. Patients can access medical services without leaving home, which is especially important for the elderly, the disabled, and those with limited mobility. Telemedicine can also help reduce waiting times for medical appointments and increase the efficiency of the treatment process through faster diagnosis and treatment. In addition, by remotely monitoring patients, such as using devices to measure blood pressure or blood sugar levels, it is possible to detect health problems more quickly and intervene faster if a patient's condition worsens. Telemedicine is increasingly used in various medical fields, such as cardiology, dermatology, psychiatry, neurology, rehabilitation, geriatrics, and many others. In Poland, telemedicine is increasingly used in various fields of medicine, both in the public and private sectors (Król-Całkowska, 2021). Here are examples of the use of telemedicine in Poland (Centrum e-Zdrowia, 2022):

- Under a pilot programme of the National Health Service (NHS), telemedicine is being used for specialised consultations. Patients have access to doctors of various specialties, such as a cardiologist, a dermatologist, a pulmonologist, a neurologist, a psychiatrist, or a endocrinologist, who provide advice and consultation via the Internet.
- Telemedicine is also used in health programmes, such as preventive programmes for patients with chronic diseases, e.g. diabetes and heart disease. Patients are given medical devices such as glucometers or blood pressure monitors to remotely monitor their health.
- In hospitals and clinics, telemedicine is used for consultations between doctors and to conduct diagnostic tests, such as EKGs or ultrasounds, in real time.
- Patients using telemedicine can also get quick access to prescriptions, test referrals or dietician advice without having to visit a doctor.
- Telemedicine is also being used for remote palliative care, providing patients with terminal illnesses access to medical care at home.

These are just some examples of the use of telemedicine in Poland. Nowadays, telemedicine is becoming increasingly popular among patients and doctors, which can help improve the quality of health care and reduce the burden on the health care system.

A reference example from outside Europe can be found in Mercy Virtual (theMercyChannel, 2019), a virtual care centre (also known as a "virtual hospital") opened in 2015 in Chesterfield, Missouri, a suburb of St. Louis, which operates exclusively through telemedicine and is the first of its kind in the world. The $54 million facility covers an area of more than 11,500 square metres and employs more than 300 physicians who care for patients who remain in their own beds in their homes and in 38 hospitals in seven states using remote solutions. Mercy Virtual is transforming health care 24 hours a day, seven days a week, 365 days a year by creating new models of care supported by telehealth teams and technology. Patients no longer need to physically seek care or completely change their lives to access specialists. Virtual technology is bringing care to them. Such a technology-enabled hospital of the future translates into improved working conditions for medical staff and patient experience, and it also allows for lower health care costs, achieving better clinical outcomes as well as contributing to reducing the carbon footprint that was associated with the need to move both patients and clinicians.

Telehealth modalities provide an efficacious and economically-advantageous mechanism for the patient–physician interaction without necessitating geographical co-location. However, there exist several limitations and considerations; there are reports indicating its limitations or challenges related to it. For example, a survey conducted recently in India showed (apart from numerous advantages) that over 50% of the respondents report communication issues and 34% report network connectivity issues. Also, 32% of clinicians report challenges in diagnosis and medical investigations (Gupta et al., 2023). This is due to the fact that medical consultations that can be effectively executed via telehealth are not all-encompassing. Clinical encounters necessitating diagnostic imaging, blood tests, or tactile examinations still mandate in-person attendance at a medical facility.

Also, the electronic transmission of confidential patient health information poses significant security risks. Ensuring the cybersecurity of data transferred via telehealth platforms remains a prominent concern that needs ongoing attention to safeguard against potential breaches.

Lastly, although insurance coverage for telehealth consultations has expanded, particularly in the context of the COVID-19 pandemic, there remains variability in reimbursement policies. Consequently, patients may encounter unexpected out-of-pocket expenses for services that are not fully covered. Thus, while telehealth offers significant advantages in terms of accessibility and cost-effectiveness, these benefits are accompanied by challenges in diagnostic limitations, data security, and insurance reimbursement (Watson 2020).

Identifying the domain of operation

Remote telehealth consultations – or medical consultations remotely using telecommunications technology – are becoming increasingly popular around the world, also in Poland. Due to the COVID-19 pandemic, they increased in popularity, because they provided a safe and convenient way to consult a doctor without having to leave home. In some countries, such as the United States, the United Kingdom, and Australia, teleporades had become common before the pandemic, and their popularity has increased over the past few years. In some countries, such as Canada, telemedicine is recognised as one form of health care, and these services are reimbursed by the national health system. In Poland, teleportation is a relatively new form of health care, but its popularity grew significantly during the COVID-19 pandemic. In March 2020, the National Health Service launched a teleportation service for patients, which is financed by the fund. Since then, many private medical companies, such as Medicover, Luxmed, and PZU Health, have also started offering teleportation services. In Poland, teleportation is available to patients on various platforms, such as mobile apps, websites, and special telemedicine platforms. Patients can consult remotely with doctors, get medical advice, receive e-prescriptions, and perform laboratory and diagnostic tests.

Emergency care vs. permanent care

Emergency care and permanent care are two different approaches to organising health care. Acute care is an approach focused on providing rapid assistance to patients in emergencies or when they require urgent medical attention. Typically, emergency care is delivered in hospitals or emergency departments. Permanent care, on the other hand, is an approach focused on the long-term health care of patients who require ongoing care or rehabilitation. This care can be provided in nursing homes, hospices, or specialised rehabilitation centres. These two types of care are important and necessary in health care, but they focus on different aspects of patients' needs. Acute care focuses on providing immediate emergency care, while permanent care focuses on long-term care for patients who require ongoing assistance or rehabilitation. In Poland, these two types of care are provided by hospitals, clinics, nursing homes, hospices, and specialised rehabilitation centres. Both acute care and permanent care are financed by the National Health Service or by patients using private medical services.

Examples

Telemedicine is applied to acute care in many ways, including through:

- *teleconsultation* – allows remote medical consultation, in which the doctor can assess the patient's condition and recommend appropriate treatment or further management;
- **remote monitoring** – allows continuous monitoring of the patient's condition using medical devices that transmit data to the telemedicine system, so that the doctor can react quickly if the patient's condition deteriorates;
- *emergency telemedicine* – allows rapid diagnosis and treatment in emergency cases, such as sudden heart attack, head injury, or other medical emergencies;
- *telemedicine* – allows for online medical consultations, which is especially helpful for people who are unable to go to a clinic or hospital in person.

Some examples where telemedicine is used in emergency care involve:

- the implementation of emergency telemedicine in Poland, which allows remote diagnosis and medical assistance by specialists in emergency cases;
- the use of teleconsultations to diagnose and treat patients with infectious diseases, such as COVID-19;
- the use of remote monitoring for continuous health monitoring of patients with chronic diseases such as diabetes, hypertension, and heart disease;
- the implementation of telemonitoring as part of preventive programmes, such as mammograms and colonoscopies.

Telemedicine has many applications in permanent care, especially for patients with chronic diseases that require constant monitoring and follow-up. Some examples where telemedicine is used in permanent care include:

- *remote monitoring* – enables continuous the monitoring of the health of patients with chronic diseases such as diabetes, hypertension, heart disease, or asthma. Patients use medical devices, such as blood pressure monitors or glucometers, which transmit data to the telemedicine system. This allows the doctor to monitor test results in real time and react if the patient's condition worsens;
- *teleconsultations* – allow remote medical consultations, owing to which patients can consult a doctor without having to leave home. Patients with chronic diseases often require ongoing treatment and follow-up, and teleconsultations allow for an effective management of their treatment;
- *telecare* – makes it possible to remotely provide medical assistance, such as changing medication dosages or recommending lifestyle changes. As a result, patients with chronic diseases have easier access to medical care and can respond more quickly to changes in their condition;

- *geriatric telemedicine* – enables remote medical care for elderly people who require constant health monitoring and assistance with daily activities. With geriatric telemedicine, they can have easier access to medical care while remaining at home and maintaining their independence.
- Some examples with specific applications of telemedicine in permanent care include:
- remote monitoring programme for patients with diabetes, hypertension, or heart disease, which allow for continuous monitoring of health conditions and rapid response in case of problems;
- the implementation of teleconsultations in health programmes for the elderly, such as geriatric care and home care;
- remote medical care for patients in hospices, enabling doctors and nurses to monitor patients' health and provide appropriate care in a timely manner.

Decarbonisation

Decarbonisation in health care (Health Care Without Harm & ARUP, 2021) is increasingly important due to growing environmental awareness and the need to reduce greenhouse gas emissions. The use of the Internet of Things (IoT) can help achieve this goal by introducing smart solutions that reduce energy consumption, cut waste, and reduce CO_2 emissions. One example of the use of the IoT in decarbonising health care is the use of smart lighting systems. This can optimise energy consumption and reduce CO_2 emissions. For example, hospitals can use lighting systems that respond to the movement of patients and medical staff, providing optimal lighting only when needed. Another example of the use of the IoT is the introduction of smart systems to monitor and manage energy consumption in hospitals. This can reduce energy consumption and associated CO_2 emissions by using energy from renewable sources, such as photovoltaic panels. In health care, the IoT can also be applied to waste management. Smart systems can help segregate and recycle medical waste, helping to reduce waste and the greenhouse gas emissions associated with its disposal. Another example of the use of the IoT in decarbonising health care is the use of telemedicine, which can reduce the number of trips that doctors have to make to see patients and reduce greenhouse gas emissions associated with transportation. This can also reduce the amount of energy used for transportation. The IoT sensors can be installed in medical devices, such as X-ray machines and CT scanners, to monitor their energy consumption. Based on this data, it is possible to determine when to perform maintenance or replace equipment, thus saving energy and reducing greenhouse gas emissions. The IoT sensors can also be used to monitor ambient conditions such as temperature, humidity, and lighting. In this way, air conditioning, heating, and lighting settings can be optimised, saving energy and reducing greenhouse gas emissions. Furthermore, the IoT can help reduce paper consumption through the use of electronic forms and documents. For example, patient medical records can be stored in the cloud and shared digitally, reducing the amount of paper used and reducing greenhouse gas emissions associated with paper production and transportation. The IoT can also enable the remote monitoring of patients, allowing doctors to monitor their health and prescribe appropriate treatment without the need for in-person visits. This, in turn, reduces the amount of the movement of patients and medical personnel, leading to a reduction in greenhouse gas emissions. Moreover, the use of electronic prescriptions reduces paper consumption and patient trips to pharmacies. It is also possible to monitor prescribed medications and avoid unnecessary repeat visits, saving time and reducing greenhouse gas emissions. Finally, the IoT can enable medical training and patient education to be conducted online, reducing the need for travel and reducing greenhouse gas emissions associated with transportation. The use of the IoT in health care can help meet decarbonisation goals by introducing smart and green solutions that reduce energy consumption, reduce waste, and reduce GHG emissions (EPA, 2021).

The research method

The domain of the study is an attempt to quantitatively analyse the carbon footprint in the implementation of health care based on telemedicine. In particular, the thesis that the use of modern communication techniques can help reduce the carbon footprint is being investigated.

The importance of the topic and the purpose of the work can be demonstrated by the implementation of the CARBON programme, which standardises the monitoring of the digital footprint in many countries. The CARBON programme aims to measure the carbon footprint of health care among 2.5 million patients from seven ongoing studies from over 40 countries (Wilkinson et al., 2022). Therefore, the development of own measurement tools, metrics, and methodology for analysing the carbon footprint is an important task. Key assumptions regarding the CARBON methodology are as follows:

- Emission calculations will be based on the type and quantity of medications prescribed or sold.
- Energy-consumption-modelling software and databases will be used for life cycle assessments of medications.
- Emissions data from the Sustainable Healthcare Coalition (SHC) will be used to evaluate the carbon footprint of health care visits.

The process of developing a research model for the purposes of this quantitative study was carried out based on the methodology of Gilbert Churchill (1979). With the advent of the Internet and technological advancements, researchers now have access to a vast amount of publicly available data that can be used for quantitative analysis. The research method is in line with the main assumptions of the CARBON methodology, especially in terms of measuring the carbon footprint for medical activities. In this work, the following model of working with data was adopted:

1. determining the domain of the research – analysing the carbon footprint of medical consultation;
2. data collection;
3. data cleaning and integration to make carbon footprint data comparable;
4. exploratory analysis, allowing for the comparison of carbon footprint data with other categories and information. At this stage, numerical assumptions are made about selected aspects of health care;
5. conclusions.

The study uses publicly available data on demographics in Poland and the data of medical services in the field of telemedicine. The following data sources were used:

1. The Central Statistical Office (GUS, 2023);
2. The Ministry of Health, The Map of Health Needs (MZ, 2023);
3. Eurostat (Eurostat, 2021).

The following data was acquired from the sources mentioned above:

1. data on the number of people living in counties and voivodeships;
2. data on the number of medical services;
3. data on the number of patients registered in the health care system;
4. data on patients outside the public health care system;

5. data on the number of ambulatory care services (ACS) and primary care services (PcS) teleconsultations in 2020–2021, broken down by voivodeships;
6. population forecasts for the years 2023–2050, broken down by counties and voivodeships;
7. Eurostat data on CO_2 emissions.

After the relevant data was identified, downloaded, and integrated, it was processed to ensure that it is suitable for analysis. This involved checking for errors, missing values, and outliers. The data also was cleaned, transformed, and formatted into a single tabular structure. This step is critical in ensuring that the analysis is accurate and unbiased. At this stage, additional calculated measures and percentage ratios were determined (Table 2).

The obtained data has different levels of detail, different time ranges, and different completeness. In order to integrate the data, it was assumed that the unit of analysis is a voivodeship, and the time granularity is one year.

The next stage of the research is exploratory analysis and data visualisation. For this purpose, we used the following IT tools for data analysis: the Python Excel and the PowerBI. A monthly list of patients enrolled into full years in a given entity providing primary care services was included. Two health care entities have been analysed: a medical entity providing services in the field of primary health care as well as night and holiday health care. The study is rooted in the ICD-10 medical care classification (WHO, 2022). Due to the nature of the data, the analysis has some limitations. Some experts question the legitimacy of using the ICD-10 system in primary health care. In addition, reporting to the National Health Fund makes it possible to report only one diagnosis code for the identification of one service, which by definition may cause interpretation limitations. In particular, during a single visit, a patient may produce several ICD-10 codes, which can be confusing. However, patient with allergies, conjunctivitis, and requiring a prescription drugs will, in fact, use several care services.

Once the data analysis is complete, the results are to be interpreted to draw meaningful conclusions. This involves analysing the output and determining the significance of the findings. They are evaluated in the context of the research question and the literature.

Data exploration

The COVID-19 pandemic brought about an important transformation in health care services, especially in the field of telemedicine. Telemedicine is the use of technology to deliver medical services and health care remotely, and it became a crucial tool for providing medical care during the pandemic. With social distancing measures and restrictions on in-person health care visits, telemedicine became an important means of maintaining patient care. The use of telemedicine has been particularly valuable for high-risk patients and those with chronic conditions who require regular checkups and monitoring. The pandemic also allowed for the development of technologies related to remote health care, such as video consultations or remote monitoring devices. The development of telemedicine during the pandemic has undoubtedly revolutionised the health care industry, providing a convenient, cost-effective, and efficient means of delivering medical care that is likely to continue even beyond the pandemic era.

During the analysis, based on the available data, the following indicators were determined (key indicators are presented in Table 2):

1. population: baseline and projections;
2. average CO_2 emissions in road transport;

3. average distances from health services;
4. indicators regarding the number of teleconsultations and the selected category of basic service;
5. the number of teleconsultations to population (percentage).

The above indicators allow the estimation of the future potential of teleconsultations and other services that can be provided using telemedicine services. Based on the population forecast for the years 2021 to 2050, the number of medical services provided remotely was estimated.

It is worth noting that data on the number of the citizens for the specific years was prepared by taking the results of the census as the starting base for a given area (voivodeship), and then making estimates using the balance method. Balance method takes into account live births, deaths, and migration balance recorded that year. The number of citizens in Poland includes two categories of population:

1. people permanently living in a specific area;
2. people staying temporarily for more than 3 months in a specific place.

The analysis did not take into account the age of the society and the fact of the ageing of the population (Fig. 1). This factor may significantly change the structure of future medical services. However, taking into account the purpose of this study and the adopted unit of analysis (voivodeship), such a simplification does not significantly affect the analysis of the carbon footprint reduction potential in the health service.

The demographic structure of Poland is presented in Figure 2. Its dynamics indicate the ageing of the society in the coming decades. Figure 3 shows the age (and sex) distribution expected in 2040. An ageing population brings various challenges to the health care system, resulting in higher costs and CO_2 emission. For example, one can expect increased demand for medical care as older people use medical services more frequently, which increases the burden on the health system. Moreover, with increasing age, the risk of chronic diseases such as diabetes, cardiovascular disease, and cancer increases. Treatment of these diseases is often expensive and long. Also, the need for long-term care services, such as nursing homes and hospices, increases with age.

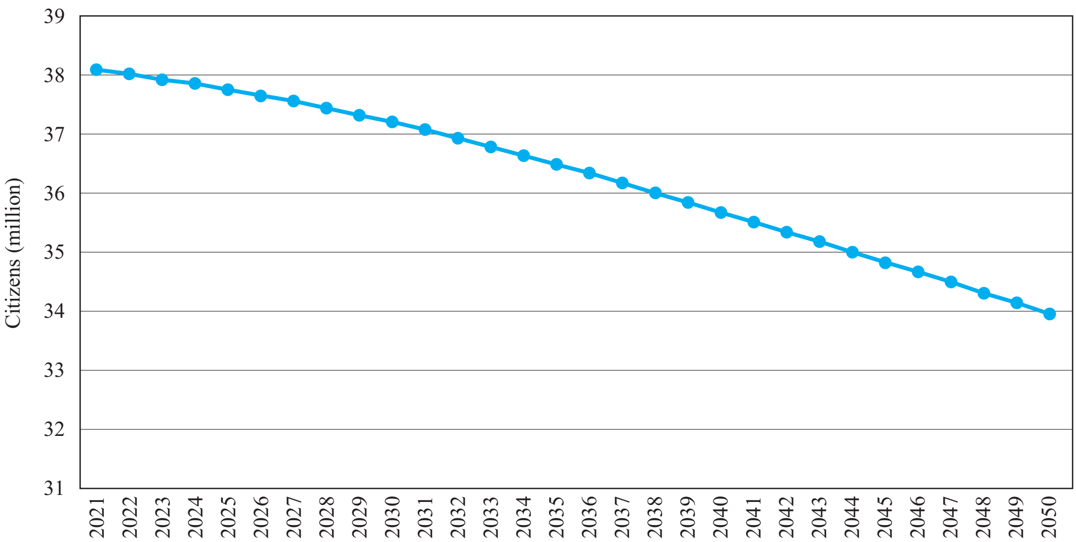


Figure 1. Predicted number of citizens in Poland from 2021 to 2050

Source: Own study.

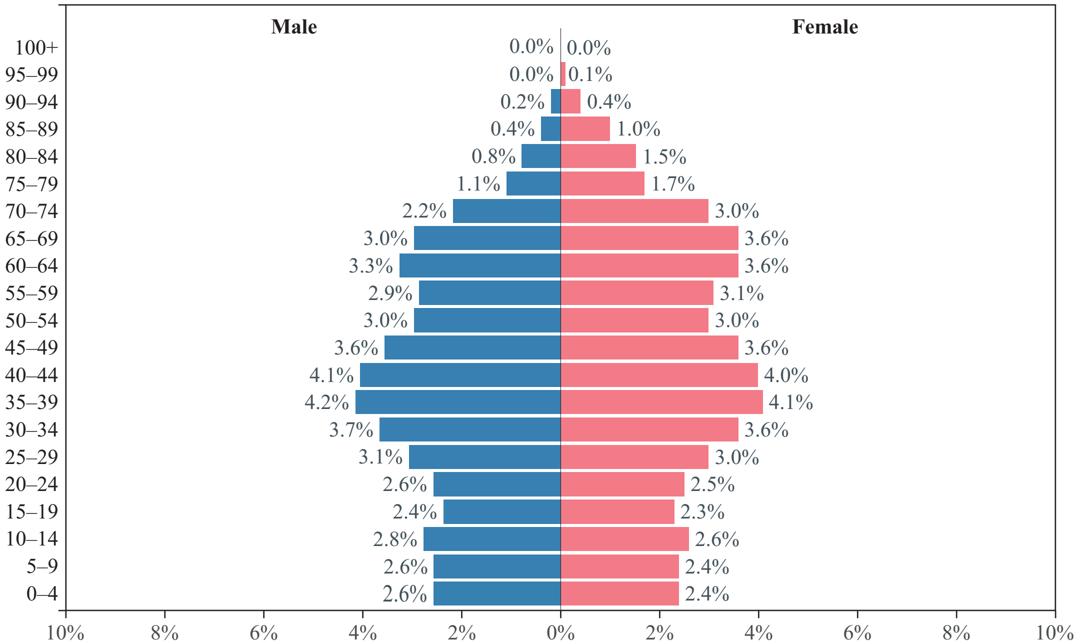


Figure 2. Age structure in Poland in 2021

Source: https://www.populationpyramid.net/

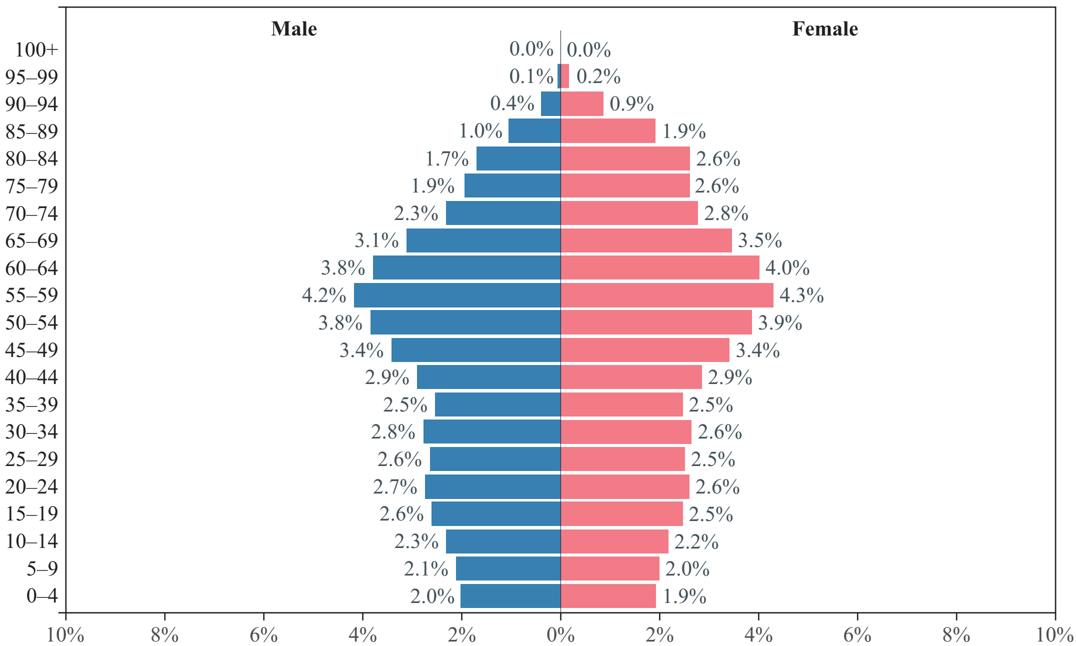
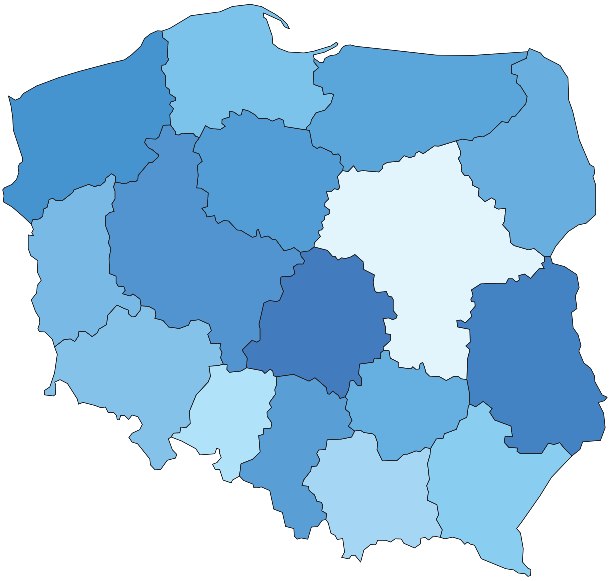


Figure 3. Predicted age structure in Poland in 2040

Source: https://www.populationpyramid.net/

Based on the historical data of the Ministry of Health, the number of basic health care services in each voivodeship was determined in relation to the number of inhabitants of a given voivodeship (Fig. 4). This measure was averaged for the whole of Poland and over time (for 2020 and 2021). The averaged indicator was used to estimate future values of the number of medical services.

In mathematical terms, the study does not take into account the factor of ageing society, although it was included in qualitative terms and in the formulated conclusions. It can be argued that the ageing of the population will generate greater needs in the field of health care. As a consequence, CO_2 emissions will increase.



Voivodeship	Services indicator
dolnośląskie	4.15
kujawsko-pomorskie	4.46
lubelskie	4.71
lubuskie	4.25
łódzkie	4.70
małopolskie	3.99
mazowieckie	3.80
opolskie	3.96
podkarpackie	4.12
podlaskie	4.31
pomorskie	4.20
śląskie	4.43
świętokrzyskie	4.34
warmińsko-mazurskie	4.41
wielkopolskie	4.52
zachodniopomorskie	4.56

Figure 4. Number of health care services for one citizen in Poland in 2021

Source: Own study.

The spatial distribution of accessibility from the place of residence to the nearest primary health clinic, expressed in a unit of distance, results directly from the location of these facilities. The Śląskie and Dolnośląskie Voivodeships are characterised by the best accessibility – 59–62% of people aged up to 17 and 64–67% of adults live here within 1 km of the clinic. For south-eastern voivodeships (Małopolskie, Podkarpackie, Lubelskie, and Świętokrzyskie) this percentage is the lowest – for children and teenagers it is 38–42%, and for adults – 43–46%, respectively. In cities, the average distance to this service is about 0.8 km, while in the countryside it is 3.4 km. About 75% people in cities live less than 1 km from a clinic – 75% of children and 79% adults. In rural areas, these percentages are 17.3% and 18.2%, respectively. Over 36% of people living in rural areas have at least 4 km to a clinic, including 13% with at least 6 km (Ajdyn, 2018). The study assumes that the average distance of a patient to a primary health care facility is 5.5 km. Thus, the total distance is 11 km (to and from the facility).

Based on this data, an indicator of the average number of primary health care services per citizen can be determined. The indicator was determined by dividing the average number of health services by the number of flats in individual voivodeships. The results determined this way were averaged, obtaining the result of 2.9 services per citizen for 2020 (Table 2).

The distance from the health care facility may vary significantly, depending on the specialisation of the medical visit. While the distance to a primary care physician is several kilometres, access to a specialist may require travelling to distant urban centres, i.e. several dozen or even several hundred kilometres away (Wootton et al., 2010).

Total CO_2 emissions from road transport are planned at 59 Mt in 2030 (an increase of 78% compared to 2005) and 51 Mt in 2050 (Rabiega & Sikora, 2020). The reduction of CO_2 emissions is realised on many levels. It concerns the implementation of electric vehicles, the development of public transport, and operational domain activities. The average CO_2 emission of passenger cars (new) in Poland in 2020 was 121g CO_2/km (Fig. 5). However, older cars have significantly worse emission parameters.

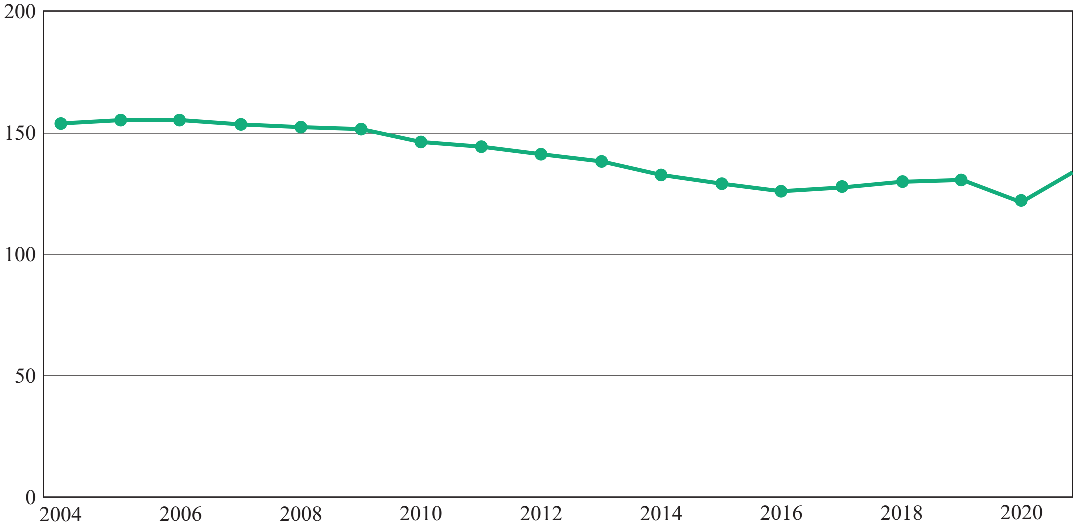


Figure 5. Average CO_2 emissions per km from new passenger cars in Poland

Source: Eurostat.

Different studies report different levels of CO_2 emissions during medical visits. For example, travelling 15 km by car produces 2.93 kg of CO_2 (Connor et al., 2019). Calculating travel distances from home addresses, also taking into account the mode of transportation and vehicle specifications, the mean saving was 39.3 km, equating to 8.05 kg CO_2 per medical consultation (Purohit et al., 2021). In turn, studies on the distances travelled to a medical facility assume slightly more optimistic emission indicators, namely at the level of 97–107g CO_2/km (Table 1). However, it should be taken into account that the emissivity depends on many elements, e.g. the terrain of the study area may cause significant changes in CO_2 emissions, while upland and mountainous areas tend to emit more pollutants (then, CO_2 levels can be as high as 152 g/km) (Vidal-Alaball et al., 2019).

In this study, we assume that the average emission of carbon dioxide per kilometre of car travel is 99 g CO_2/km. Thus, it can be calculated on average that one medical consultation results in 1.1 kg of CO_2 emissions (Table 2).

Table 1. Distance and average CO_2 emissions by car in selected studies

Travel distance [km]	CO_2 emission per consultation [kg CO_2]	CO_2 emission per 1 km [g CO_2]	Source
39	8.1	103	(A. Connor et al., 2011)
15	2.9	98	(M. J. Connor et al., 2019)
18	3.6	98	(Miah et al., 2019)
111	22.0	99	(Oliveira et al., 2013)
21	3.3	76	(Vidal-Alaball et al., 2019)
126	26.9	107	(Wootton et al., 2010)

Source: Own study based on (Purohit et al., 2021).

Another approach involves the analysis of all therapy and patient care, using remote means. For example, comprehensive life cycle assessment (LCA) was carried out in Sweden to estimate the carbon footprint of the telemedicine equipment (Holmner et al., 2014).

Table 2. The main assumptions and metrics of the study

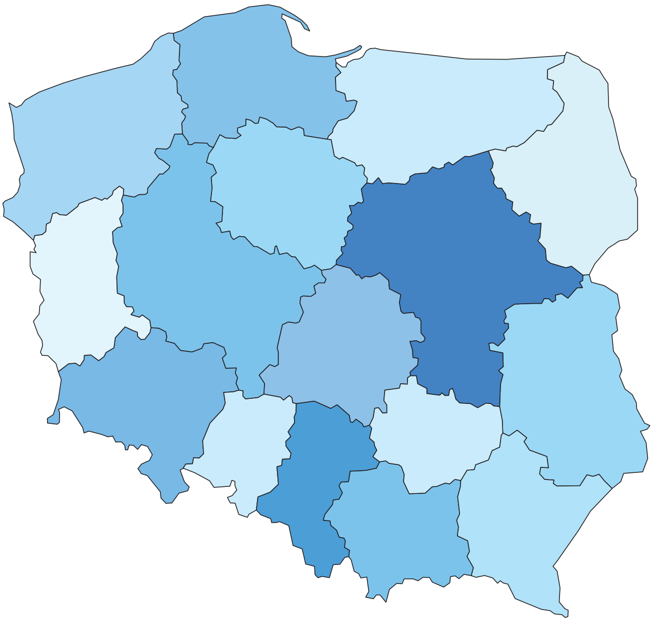
Metric	Value	Source
Average distance to a healthcare facility	5.5 km	(Ajdyn 2018)
Average CO_2 emissions/km	99 g	(Oliveira et al. 2013)
Average CO_2 emission per one medical consultation in the facility	1.1 kg	11km x 99g
Average number of primary care services per person	2.9	
The percentage of teleconsultations among medical consultations	25%	
Percentage of prescription renewals among medical consultations	41%	
Percentage of consultations on behalf of another person among all medical consultations	5%	

Source: Own study based on literature review.

In Poland, in 2021, over 39 million remote visits were carried out. Taking into account the population of the country, once numerous patients were registered, it constitutes 24% of all services provided in this period (Fig. 6 and 7). For further analyses, it was assumed that 25% of medical services are teleconsultations (Table 2).

The years 2020 and 2021 covered the period of the pandemic and the greatest restrictions related to movement and public gatherings. In those years, respectively 0.3 and 1 consultation per person were carried out (in relation to the number of inhabitants of the country). Taking into account the projected population and the corresponding number of health services, it can be assumed that the number of teleconsultations in 2040 will be at the level indicated in Figure 8.

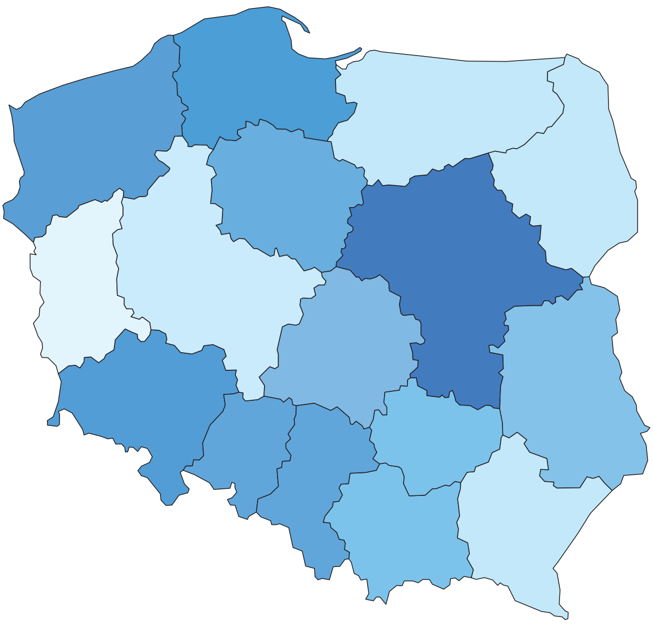
It is worth noting that a significant number of medical services provided as part of primary health care include renewals of prescriptions and consultations on behalf of another person (2.8 million in 2020 and 1.7 million in 2021). Both categories, if properly managed, could be successfully implemented remotely to a large extent. Saving time, reducing patient service costs, or reducing pollution caused by commuting to a medical facility can certainly bring measurable benefits, especially in the long term, when telemedicine and the use of the IoT will be used systemically in health care.



Voivodeship	Telekonsultations (POZ)
dolnośląskie	3,243,435.00
kujawsko-pomorskie	2,265,594.00
lubelskie	2,254,961.00
lubuskie	781,653.00
łódzkie	2,668,714.00
małopolskie	3,175,463.00
mazowieckie	6,213,484.00
opolskie	994,013.00
podkarpackie	1,707279.00
podlaskie	971,986.00
pomorskie	2,705,874.00
śląskie	5,069,012.00
świętokrzyskie	1,235,406.00
warmińsko-mazurskie	1,213,040.00
wielkopolskie	3,084,202.00
zachodniopomorskie	2,008,020.00

Figure 6. Number of teleconsultations in Poland in 2021

Source: Own study.

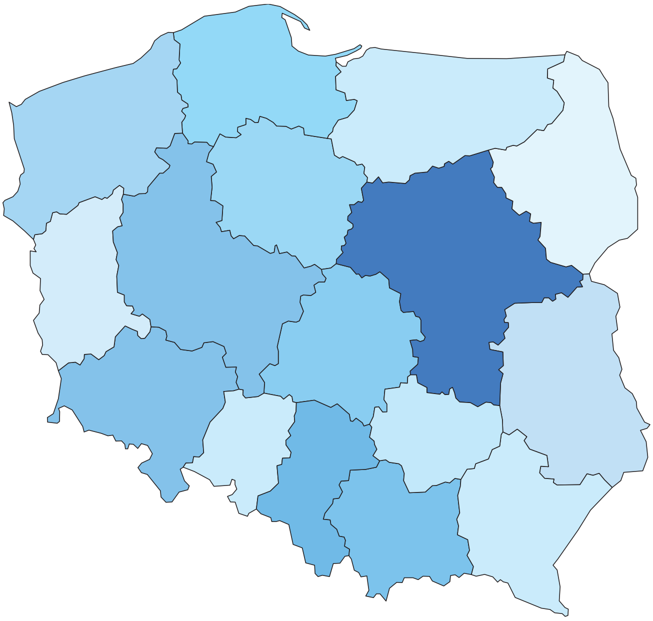


Voivodeship	Teleconsultations percentage
zachodniopomorskie	26,26
wielkopolskie	19.54
warmińsko-mazurskie	19.57
świętokrzyskie	23.50
śląskie	25.68
pomorskie	27.46
podlaskie	19.36
podkarpackie	19.64
opolskie	25.91
mazowieckie	30.20
małopolskie	23,33
łódzkie	23,48
lubuskie	18,41
lubelskie	23,04
kujawsko-pomorskie	24,81
dolnośląskie	27,11

Figure 7. Number of teleconsultations in Poland in 2021 as a percentage of all medical services

Source: Own study.

In this paper, we point out that the use of innovative remote health care tools can also help reduce the carbon footprint of some medical services.



Voivodeship	Telekonsultations (POZ)
zachodniopomorskie	2,573,481.77
wielkopolskie	3,801,617.47
warmińsko-mazurskie	1,158,159.21
świętokrzyskie	1,425,903.39
śląskie	4,275,887.21
pomorskie	2,890,932.76
podlaskie	700,304.65
podkarpackie	1,368,855.13
opolskie	1,135,789.65
mazowieckie	8,245,380.08
małopolskie	3,896,051.54
łódzkie	3,141,934.76
lubuskie	818,510.90
lubelskie	1,394,604.16
kujawsko-pomorskie	2,699,006.90
dolnośląskie	3,500,695.67

Figure 8. Predicted number of teleconsultations in 2040

Source: Own study.

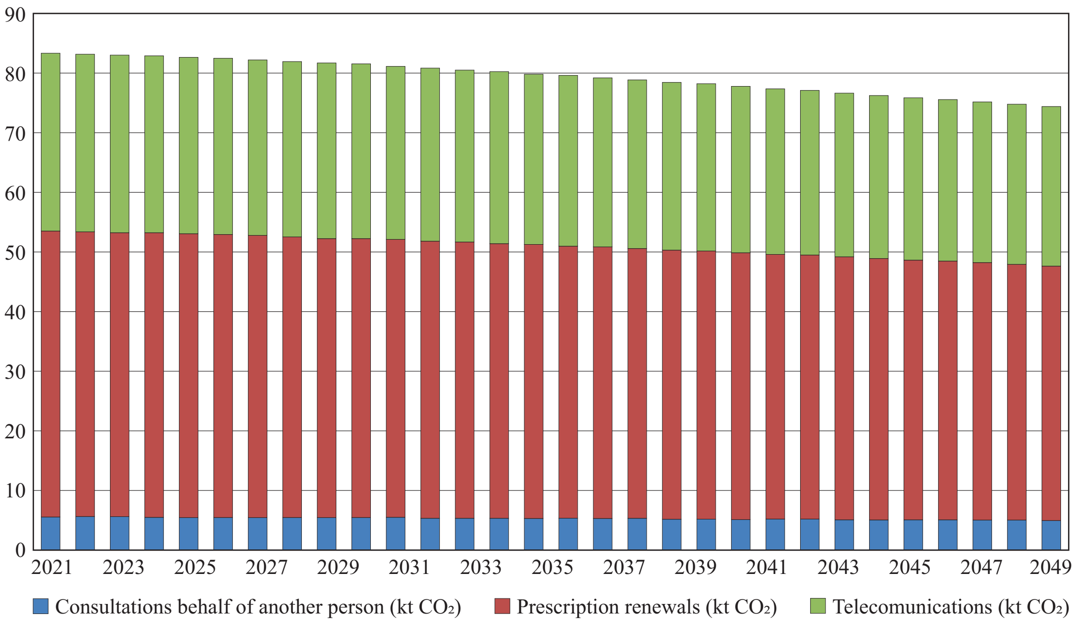


Figure 9. Projected amount of CO_2 reduction in kilotons per year

Source: Own study.

Consultations on behalf of another person account for approximately 5% of all services provided as part of primary health care. Prescription renewals account for over 40%. For further analyses, we assume that 5% are consultations on behalf of another person and 41% of all medical services are prescription renewals (as presented in Table 2). Assuming that the level of teleconsultations (i.e. their percentage in relation to the total number of services provided) will be constant over time, three forecasts of the possible reduction of the carbon footprint were presented, coming from car trips to a health care facility. Potential CO_2 savings can be made in three categories. Taking into account the dynamics of Poland's population over time, the estimated CO_2 reduction will be as indicated in Figure 9.

When analysing the potential reduction of the carbon footprint by means of IT and video systems, it should be related to the carbon footprint produced by these systems. For example, a study in Sweden (Holmner et al., 2014) used a ‚cradle-to-grave' life cycle assessment (LCA) to evaluate the carbon footprint of videoconferencing equipment. The study concluded that the carbon footprint from telemedicine equipment is relatively small (1.86–8.43 kg CO_2/hour) compared to car travel for in-person visits (87.4–176 kg CO_2 saved per consultation). Carbon footprint reported in the University of California, Davis Health System's outpatient telemedicine service, reports savings of total of 1,969,000 kg CO_2 across 19,246 consultations (Dullet et al., 2017).

There are some limitations in comparing different results, as some studies did not account for the travel distances of health care professionals. For example, a study in Scotland (Wootton et al., 2010) found that videoconferencing in nurse-led minor injuries units avoided unnecessary transfers, saving an estimated total of 260,000 km of travel, or 26.9 kg CO_2e per consultation. Some studies have looked at cost-effectiveness per consultation, with different assumptions being made to determine the environmental cost of consultation. Other studies operate on aggregated data, which can then be averaged per consultation, and still others are based on the number of travel kilometres saved during the Internet or telephone communication.

Conclusions

The study reported that the use of telemedicine services leads to a reduction in the carbon footprint of health care. The health care sector is responsible for about 4.4% of global greenhouse gas emissions, which indicates that the exploration of this area is important for emissions of GHGs. The relationship between the carbon footprint and the average travel distance is known and strong. Many CO_2 emissions reductions come from a reduction in travel to on-site consultations. We suggest that telemedicine should play an increasing role, especially in an ageing society that will require more medical consultations over time.

In weighing the results of this study, several limitations should be considered. First, the applied research method does not allow for the generalisation of the research. In particular, the analysis does not take into account the dynamics of demographic changes in society. However, some regularities and guidelines may be indicated as valuable, even despite this limitation. The second limitation of the analyses is the use of private care by patients. In addition, the patient's place of residence may not correspond to the reality, because it is based only on his/her declaration, which, in turn, is submitted relatively rarely.

The directions of further research result from the limitations of this study. Further research should focus on two areas:

- an analysis of future medical needs, taking into account demographic dynamics and using innovative telemedicine tools;
- the use of modern methods of communication and medical diagnostics in remote patient services.

Despite the indicated limitations, the study brings specific numbers and indicators that not only show the state of the health care carbon footprint today, but also indicate the future values of selected indicators. The essence of the study is to base it on relatively simple assumptions, the modification of which might increase the dynamics of analyses with the scenario-based approach.

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