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Increasing consciousness and responsibility in several fields of sustainability

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doctoral dissertation

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Preface

After finishing my studies in Actuarial Sciences at the Corvinus University of Budapest (CUB), I carried out activities as an actuary and product developer between 2006 and 2014 in Hungary and in the Netherlands. Subsequently, I could get in touch during 1-1 year with the civil sector and later the information and communication technology (ICT) sector. In 2018, I turned to the field of sustainable development by performing assignments as a volunteer in favour of non-governmental organisations (NGOs). I started my PhD studies in Sustainability Management in 2019 at my alma mater.

In Greek mythology, Prometheus, one of the Titans, gave humanity fire in order to accelerate its development and raise it from the uncivilised circumstances. Nowadays, the tools of sustainable development represent an analogous set of knowledge, technology, and proposal on behaviour required to ensure the integrity of our planet and bequeath it in a decent status to future generations.

This dissertation was actuated by my motto formulated from interactions with the National Society of Conservationists. It sounds as follows: 'The early mass recognition that smart modern Davids weaponised with knowledge and wisdom can defeat planetary crises such as species loss and global warming without entering any battle nurtures my hope that the 21st century will be the triumph of rationality and the rise of mankind.' My credo was and is shaped by many streams, wisdom, and science. I applied the sharp-witted saying of Mahatma Gandhi in such a way that it corresponds to the zeitgeist of our era, the Anthropocene. Becoming a hermit abandoning society works as rara avis but representing a globally viable paragon following the easily and rapidly implementable principles of sustainable development coupled with the abundance of its benefits can be appealing or persuasive for all individuals or corporate actors. Being one of the enthusiastic proponents of knowledge-based societies, I profess that putting science on its deserved pedestal can help in surmounting global problems.

Acknowledgements

I sincerely would like to thank all of my teachers irrespective of the institution and my former colleagues for widening my knowledge and funding my multidisciplinary, future-oriented, system-level approach. I wish to acknowledge Gábor Harangozó for his untiring conscientious support throughout the entire duration of the last five years. I am grateful for the valuable contributions of further colleagues of the Institute of Sustainable Development of CUB (Mária Csutora, Anna Széchy, Zsuzsanna Szerényi Marjainé, Gabriella Pál, Sándor Kerekes, Tamás Kocsis) and for the recurrent contact with György Pataki. I greatly appreciate the kind gesture of Erzsébet Kovács to remind me of the importance of learning when I worked at Aegon Hungary Composite Insurance Company. I express my thanks to Ágnes Zsóka for identifying in me the potential for evolving into a university professor/researcher and directing my attention to the PhD programme starting in the autumn of 2019 after I hesitated in 2006. Nonetheless, the first feeling proved to be the right choice and it could come true resulting in finding my way. László Gulácsi deepened my affinity for health sciences. Special note must be taken of the coordination rendered by Annamária Ónodi and the Doctoral Office. I truly love my university because I can carry out two of my favourite activities, namely, teaching in various fields of Economics and as a researcher diving into data and revealing findings. In addition, I could and can always learn and be inspired by the interactions with my students either as a lecturer or as a supervisor.

The impulses provided by community partners such as Smile Foundation, Hungarian Interchurch Aid, Non-profit Information and Training Centre Foundation, Hungarian Food Bank Association, National Society of Conservationists – Friends of the Earth Hungary, KÖVET Association for Sustainable Economies, and Heroes of Responsible Dining Foundation proved to be indispensable for complementing my view of thinking with societal and environmental angles. Thanks to them, I could gain some insight into the qualities of a committed environmental defender, an alternative homo oeconomicus, and active citizenship embracing constructive initiatives. Last but not least, I could count on the uninterrupted assistance of my family and relatives in doing my PhD studies.

I. RESEARCH FRAMEWORK

1. Introduction

This work follows the structure of an article-based doctoral dissertation complying with the B version by relying on five published studies. The articles present the results of extensive research conducted in the course of 2.5 years. Based on the classification system of the Journal of Economic Literature (JEL), this cross-disciplinary study can be classified into the categories listed below (*AEA, 2023*):

a) Health, Education, and Welfare:

I15 (Health and Economic Development),

b) Agricultural and Natural Resource Economics, Environmental and Ecological Economics:

Q01 (Sustainable Development),

Q53 (Air Pollution; Water Pollution; Noise; Hazardous Waste; Solid Waste; Recycling),

Q54 (Climate; Natural Disasters and Their Management; Global Warming).

Nearing the target year of 2030 related to achieving the Sustainable Development Goals (SDGs), sustainability-related content diffuses more intensively the tissue composed of individuals, the circle of corporate actors, and the nexus between them. Shifting from a conventional view towards a more complex approach involving all subsystems manifests itself in proliferating signs. Both the demand and the supply of products and services with environmental or a broader sustainability focus are augmenting, which enables customers to make conscious decisions. The exigencies can spill over into all corporate operations. In the case of individuals, opting for the use of renewable energy or preferring savings with the purpose of environmental protection can help in mollifying sustainability concerns. Regarding firms, disclosing scope 1-3 carbon dioxide emissions, reducing air pollutant intensities in industries and manufacturing branches, demonstrating progress in digitalisation, applying environmental management tools, e.g. standards such as EMAS (Eco-Management and Audit Scheme), ISO 14001 (environmental management system), or ISO 50001 (energy management system) are a few examples of measures forming part of the present stage of Anthropocene. Not only

within but also outside the economy, a plethora of initiatives promotes environmental or social issues. Nonetheless, the accomplishment of SDGs should be accelerated globally in order to counterbalance human activities with devastating effects and restore the delicate equilibrium amongst the subsystems. Without generalising, the hegemony of overproduction causes overexploitation of nature (accompanied by diminishing assimilating capacity and increasing pollution) and supports and necessitates overconsumption. As a consequence, the environment is overloaded and the process of reaching its limits is hastened, the health of individuals is overstrained due to civilisational harms, and health systems are overburdened. The SDGs offer a lasting remedy to break out of this vicious circle.

For the first time, I got acquainted with the framework of sustainable development in 2018, when I became a volunteer at the National Society of Conservationists – Friends of the Earth Hungary. I realised that a substantial subset of these objectives (3rd SDG – good health and well-being, 11th SDG – sustainable cities and communities, 12th SDG – responsible consumption, 13th SDG – climate action) could be directly influenced at the level of customers. (*United Nations, 2015, p. 14*) In a considerable share of the cases, noteworthy positive changes can be achieved within a short time by dedicating a relatively low level of time, effort, or expenditure to these territories. My postgraduate studies were imbued with the intention to collect effective arguments and reveal interrelationships, which can induce the inclination to participate in this transformation and reap its benefits.

In 2019, my enthusiasm about and commitment to Sustainability Management designated the choice for the specialisation of the PhD studies. Being an active practitioner, I am convinced of the beneficial impacts and the necessity of the tools of sustainable development. As a kind of herald of this approach, I attempt to spread the idea in the circle of both individuals and companies via articles in papers. The AIDA model, commonly applied in marketing communication, proved to be useful in finding orientation on how to deal with argumentation and how to transmit impulses when preparing studies in the research field. The acronym builds on the consecutive stages of attention (A), interest (I), desire (D), and action (A). The first step is raising the attention of the target group, secondly, obtaining its interest by inducing, improving, or changing values and attitudes, then, engendering desire for acting, and finally, taking action represent the phases. (*Horváth–Bauer, 2013, p. 65*) Amongst others, I am actuated by

lessening the environmental load and anchoring sustainable human well-being. On the one hand, disclosing interrelationships and opportunities which can help in tackling both climate change and air pollution constitutes the lion's share of this work. On the other hand, my motivation rests on ameliorating healthy life expectancy.

Sustainable development is a comprehensive research field with innumerable ramifications. Although a cardinal part of the research was performed in the past decades, future opportunities remained to throw new light upon current findings and widen the accumulated knowledge in both depth and breadth. The presented interrelationships aim to provide a contribution to the state of the art of the underlying disciplines. The overarching main research question (RQ) targets enlarging the findings on how to accelerate the achievement of SDGs connected to health and well-being, digitalisation, and tackling climate change by mobilising individual actors. The applied bottom-up approach leads from the level of citizens and corporates to that of policymakers. In the plethora of SDGs, good health and health consciousness, corporate sustainability with a focus on competitiveness, and environmentally conscious consumer behaviour in general and peculiar to prosuming and mobility come to the fore.

As a consequence, these results and recommendations may exercise their effects by strengthening both the resilience and competitiveness of the economy in tandem with restoring the integrity of the environment and improving the well-being of society. Furnishing stakeholders with valuable findings may improve pro-environmental and health-conscious behaviour as well as contribute to both (i) risk awareness as a corollary of deepening knowledge and (ii) an accompanying reaction manifesting itself in risk aversion. Refining the toolkit of decarbonisation and beyond it, that of environmental protection coupled with that of digitalisation, promoting the diffusion of cleaner technologies, bolstering the transition to carbon neutrality, advancing its date, and both citizens and companies getting in durable harmony with the society-environment-economy system would be the ideal farther aftermath of the articles.

Based on a comprehensive risk-based approach, the next chapter (Theoretical background) deals with notions and phenomena as well as provides a brief summary of the current state of the topics addressed in the articles. Furthermore, it creates a nexus between the studies in addition to the evident common categories represented by the particular research fields.

2. Theoretical background

The structure of this monograph follows the rationale of a risk-based approach relying on the understanding of system dynamics, planetary boundaries, the aftermath of global warming, and major health risks and impairments plus not losing the solid foundation of small and medium-sized enterprises (SMEs) in the competitiveness of a country's economy. In line with this approach, the dissertation begins by expounding the risks coupled with global warming, then, the advancement in decarbonisation or – from a broader view – sustainable development in terms of international agreements and the main strides of Hungary. Investigating the antecedents of its decarbonisation from the late 1980s and its legal environment, shedding light on the recent state of the landscape of SMEs, revealing the recent state of health of the Hungarian society, describing the level of both environmental and health consciousness complemented with values, norms of alternative economic theories and the theory of planned behaviour constitute the context in which the five articles can be coherently placed.

Primarily, the findings enable to designate the critical areas to be developed in the case of Hungary, but the results can serve as an orientating basis for other countries as well.

2.1. Background of climate concerns: risks associated with global warming at a glance

This section elucidates the main risks and sectoral impacts associated with global warming. Nowadays, mankind faces drastically the resource limits and ecological thresholds of Earth, which are represented by nine scientifically underpinned planetary boundaries. These are recapitulated in Table 1.

1. Table: The nine planetary boundaries
(Richardson et al., 2023, pp. 4-5)

Earth system process	Control variable	The last available state based on the control variable
1. Climate change	a) atmospheric CO_2 concentration b) change in radiative forcing	a) **transgressed**: zone of increasing risk b) **transgressed**: high-risk zone
2. Ocean acidification	carbonate ion concentration	approaching the planetary boundary: safe operating space

Earth system process	Control variable	The last available state based on the control variable
3. Stratospheric ozone depletion	stratospheric O_3 concentration	safe operating space
4. Nitrogen (N) and phosphorus (P) cycle (biogeochemical flows)	a) N: amount of N_2 removed from the atmosphere for human use b) P: at the global level, P flows from freshwater systems into the ocean at the regional level, P flows from fertilizers to erodible soils	a) N: **transgressed**: high-risk zone b) P: at the global level, **transgressed**: zone of increasing risk at the regional level, **transgressed**: high-risk zone
5. Freshwater change	a) human-induced disturbance of blue water flow b) human-induced disturbance of green water flow	a) **transgressed**: zone of increasing risk b) **transgressed**: zone of increasing risk
6. Land system change	a) global: area of forested land as the percentage of original forest cover b) biome: area of forested land as the percentage of potential forest	a) global, **transgressed**: zone of increasing risk b) tropical, **transgressed**: zone of increasing risk (Americas) or high-risk zone (Africa, Asia) temperate, safe operating space (Americas) or **transgressed**: zone of increasing risk (Europe, Asia) boreal, **transgressed**: zone of increasing risk (Eurasia) or high-risk zone (Americas)
7. Change in biosphere integrity	a) genetic integrity: extinction rate defined as the number of species per million species per annum b) functional integrity: human appropriation of the photo-synthetic energy and materials flow into the biosphere (HANPP) divided by the net primary production of the Holocene (Holocene NPP)	a) genetic integrity: **transgressed**: high-risk zone b) functional integrity: **transgressed**: high-risk zone
8. Atmospheric aerosol loading	interhemispheric difference in Aerosol Optical Depth	safe operating space
9. Novel entities[1]	percentage of synthetic chemicals released to the environment without adequate safety testing	**transgressed**: high-risk zone

[1] The planetary boundary of novel entities hints at the disruption of material cycles or the problem represented by the waste of synthetic chemicals and substances. Owing to the attribute 'novel', control variables with pre-industrial values do not exist, hence, the decision rests on the comparison between the annual production of chemicals (including plastics) and their release to the environment on the one hand and the global capacity for their assessment and monitoring on the other hand. (*Persson et al., 2022, p. 1517*) The anthropogenic (or human-made) mass – subject to exponential growth (doubling approximately every 20 years) – is expected to surpass the totality of global living biomass in terms of dry weight. Solely the weight of produced plastic exceeds by far the mass of animals altogether. The absolute value of anthropogenic mass waste is uninterruptedly augmenting. (*Elhacham et al., 2020, pp. 442-444*)

By classifying them into a two-level hierarchy, climate change and biosphere integrity are the two core boundaries, which are linked to all of the seven non-core boundaries. The nine boundaries designate a safe operating space, a desirable framework in which mankind can keep thriving when major cautions represented by boundary interactions and scale (levels of decision-making) are considered. As the global economy has become inconsistent with the ecological conditions in the past decades, six boundaries have been already transgressed by humanity, while those with currently not crossed thresholds are exposed to risks and destabilisation as well since the Earth-system processes are tightly interconnected. Uncertainty characterises the time needed to cause environmental changes that jeopardise the ability to return to safe levels. These omens necessitate to review orthodox economics through a paradigm shift towards globeconomics investigating the ecological boundaries of the entire world economy and aiming at the balanced development of national economies without any extreme forms of inequality. (*Rockström et al., 2009, pp. 474-475; Steffen et al., 2015, pp. 1, 8; Tóth, 2022, p. 1486*)

After overstepping the listed limitations (e.g. exceeding the proposed atmospheric CO_2 concentration), the corollaries may be characterised by possible decay through disastrous consequences as first, the safe operating space is replaced by the zone of increasing risk, then, humanity enters the area of high risk. As an example, it is worth noting that (i) changes in land and sea use (including habitat loss and degradation), (ii) species overexploitation, (iii) invasive species and disease, (iv) pollution, and (v) climate change are the five main threats to biodiversity according to *WWF* (2020, p. 20). However, cessation of the obsession with conventional growth and encouragement to pursue a new paradigm centred on sustainable human well-being may restore the delicate equilibrium between the planetary boundaries. By highlighting decarbonisation, the economic subsystem can directly soften the impacts arising from climate change. Additionally, this process may slow down the loss of biodiversity, halt ocean acidification[2], and improve the resilience of ecosystems, etc. As each of the natural,

[2] The average pH (taking the decadic logarithm of the concentration of oxonium ion) of the surface waters of the ocean is around 8.1 nowadays, which is likely to drop to 7.8 by 2100 based on business-as-usual scenarios, i.e. the acidity of the ocean increases by approximately $99.5\%(=10^{-7.8}/10^{-8.1}-1)$. In the ocean, rising CO_2 concentration arising from the atmosphere augments the concentration of HCO_3^- by reducing that of CO_3^{2-}($CO_2+H_2O+CO_3^{2-}\rightarrow 2HCO_3^-$). The ocean pH has been around 7.8 in the epoch of the Miocene

human, and man-made capital is preserved, striving towards carbon neutrality and eradicating air pollution can ensure strong sustainability. (*Costanza et al., 2013, p. 73; Kerekes et al., 2018, pp. 32, 47; Richardson et al., 2023, p. 4*)

Irreversible after-effects attach even to more favourable scenarios. As one of the major corollaries of further anthropogenic emissions, long-term changes in the climate system (e.g. sea level rise and its impact on the population, increase in mean temperature) may occur. Besides, the frequency and impacts of extreme weather events (e.g. droughts, heatwaves, and rainfall) may be amplified e.g. those born in 2020 are expected to be exposed to heatwaves four times (1.5-degree scenario) or six times (2-degree scenario) more in their lifetimes than the cohort born in 1960. Global warming may entail more deleterious impacts on biodiversity and ecosystems (comprising species loss and extinction, degraded state of ecosystems or their transformation from one type to another e.g. deforestation), furthermore, in the case of the ocean, it exacerbates the rise in both temperature and acidity as well as the decrease in oxygen levels. Regarding the scenario of 1.5°C, the area at risk of transformation of ecosystems is predicted to be approximately 50% lower compared to 2°C. In the case of the 2°C target, more carbon dioxide emissions may be released through melting permafrost areas. Ultimately, higher climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth, as well as more adaptation needs are projected. (*IPCC, 2018, pp. 6-13; McKay et al., 2022, pp. 3, 6; UNDP, 2022, pp. 109-110*)

Insufficiency of climate actions may precipitate the exacerbation of global warming. Even succeeding in restricting the increase in the global average temperature just below 2°C can trigger multiple climate tipping points, both global core and regional impact ones. A few examples of the possible main cataclysms brought on by global warming if the 2-degree scenario is realised are sea level rise due to ice sheet meltdown in Greenland and Western Antarctica, widespread bleaching of low-latitude coral reefs, thawing of permanently frozen boreal permafrost areas by releasing GHGs, and loss of extra-polar mountain glaciers. Further warming is likely to cause more devastation around the globe. (*Kipp-Elemente, 2019, pp. 22-23; McKay et al., 2022, pp. 2-3, 5-7*)

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and was characterised by extinction events. The anion CO_3^{2-} is indispensable for calcifying organisms to build and maintain their calcium carbonate ($Ca^{2+}+CO_3^{2-}\rightarrow CaCO_3$) structures. (*NOAA, 2023*)

Rapid penetration of more sustainable alternatives in all sectors (e.g. low- or zero-carbon energy sources, fossil fuels or hard-to-abate residual emissions coupled with carbon management, improving the efficiency of both energy and material use, circular economy, transforming production processes, and demand-side measures affecting both infrastructure design and use, end-use technology adoption, and sociocultural and behavioural factors) is assumed in the previous scenarios. Regarding mitigation, the affordability of low-emission technologies increased thanks to the spectacular drop in unit costs between 2009 and 2019 worldwide (e.g. cost of batteries for passenger electric vehicles, price of both photovoltaic /PV/ and onshore wind electricity) and adequate innovation policies support their global diffusion. In the case of the 2-degree pathway, the cost of mitigation is expected to remain below the harvestable global economic benefit. This relation may serve as a reasonable economic argument for the world's leaders to accelerate the current speed of decarbonisation (more emphasis on mitigation than on adaptation) and remain within the threshold of 2°C. In addition to preventing or attenuating harmful interference with the climate system, coordinated climate mitigation and adaptation are of paramount importance for achieving sustainable development. (*IPCC, 2022, pp. 11-12, 17, 24, 29, 34-37, 40, 42; UNDP, 2022, pp. 162-163*)

At the global level, climate and further environmental challenges of the Anthropocene are expected to escalate into a source of instability and severe threats manifesting themselves inter alia in political conflicts, food insecurity, forced migration, or redefined economic, trade, and security interests. Addressing these perils requires (i) internalising climate and environmental concerns by decision-makers, (ii) heightening resilience, and (iii) fostering a just transition around the globe. (*EC, 2019, p. 21*)

Lange et al. (2020, pp. 1, 10-11, 16) examined the impact of climate change on the land area and population by virtue of six categories of extreme events. Their ensemble consists of (i) river floods, (ii) tropical cyclones, (iii) crop failure, (iv) wildfires, plus the two largest contributors, i.e. (v) droughts and (vi) heatwaves. Based on the projections, climate change will beset the countries unevenly: the tropical and subtropical regions will be hit by more abrupt temperature increases than the rest of the Earth, and the most vulnerable in terms of overall exposure is South Asia.

The future of the less affected European scene is alarming as well. By taking a pessimistic scenario of Germany, temperatures can climb to 4°C by 2100 compared to

1971-2000 levels. In this scenario, the number of days where the highest temperature is above 30°C may triple and by 2050, the mean temperature in winter may augment by 3°C from the level of 1990. The number of people beset by floods may culminate from recent 100 thousand inhabitants to 700 thousand by 2040. (*Jacob, 2019, pp. 24-26, 29*)

With particular reference to the Carpathian Basin, current climate trends are expected to continue: the precipitation is and will be concentrated on fewer days, the proneness to drought is exacerbating, and the frequency of heavy precipitation events keeps growing. Pessimist scenarios anticipate a 3.5-4.5°C accrual in mean temperature by the end of our century. The number, the average length, and the intensity of long-lasting heatwaves will expand by aggravating the climate impacts, especially in the form of longer summer arid periods. Weather extremities will worsen in frequency and intensity. The precipitation intensity is predicted to increase. (*MIT, 2020a, pp. 6-8, 13*)

Table 2 is a compendious description about the major sectoral impacts of changes in climate parameters[3] for the 21st century affecting primarily the population, agriculture, forestry, fishing, energetics, tourism, and the built environment. (*MIT, 2020a, pp. 4-5*)

2. Table: Impacts of changes in climate parameters in the Carpathian Basin
(MIT, 2020a, pp. 4-5, 17-18)

Spatial and temporal change in precipitation and temperature:
Rivers (summers characterised by scarcity of water, winters by floods)
Great lakes (deteriorating both water balance and water quality)
Underground water reserves (change in quantity, quality, and availability)
Decrease in ecosystem services, expansion of invasive species
Reduction in stocked forest area, carbon storage and sink capacity accompanied by carbon dioxide emissions as a consequence
Augmenting proneness to drought
Appearance of new pests and disease-causative agents
Prolonging vegetation period
Moderating energy needs for heating, enhancing electricity need for cooling
Change of the precipitation intensity:
Flash floods
Swelling damages sparked off by storms
Proliferating sources of geological hazards (heavy and sudden rains)
Heatwaves
Change in clouds and global radiation:
Utilisation of solar energy
Increase in ultraviolet radiation:
Growing number of persons suffering from a tumour

[3] In addition, other air pollutants endanger and harm natural, human, and man-made capital, e.g. in the form of acid rains, but these are left out from the table.

As a stylisation of the SDG wheel, Figure 1[4] sheds light on the interconnectivity of SDGs and points out that achieving good health and well-being (3rd) and taking action against climate change (13th) are mutually interwoven (e.g. financial priority is given not to climate but to human health which is negatively affected by aggravating global warming). In addition, further SDGs enhance the complexities of both selected SDGs which play a central role in this document. Each of the articles endeavours to provide findings fostering sustainable development. Not counting the first article which is related to the 3rd SDG, the studies aim at contributing to decarbonisation at the level of corporate actors (especially SMEs) and individuals.

1. Figure: Causal dependencies between SDGs represented by main areas
(Each arrow starts from the prerequisite.) *(United Nations, 2015, p. 14)*

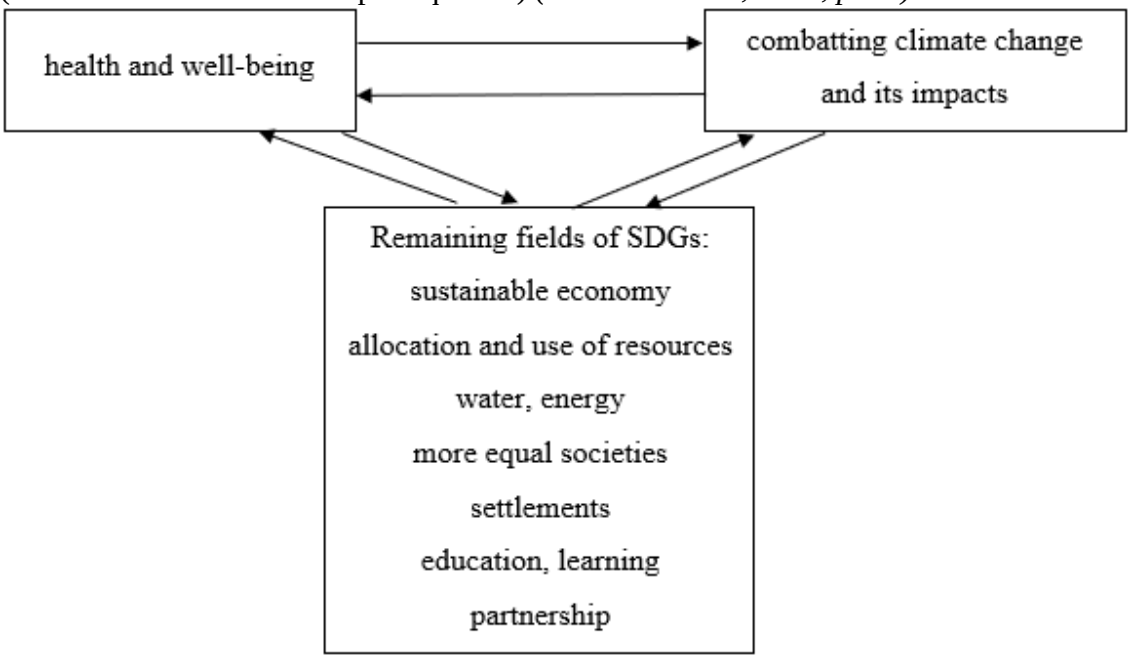


Table 25 in the Appendix recapitulates the major stages and highlights of the decarbonisation efforts and the transition to sustainable development from the early 1970s until the early 2020s by encompassing the antecedents and recognition of the necessity for sustainable development and the actions against climate change.

[4] Figure 1 of Section 4.1 illustrates a slice of the interconnectivity of SDGs with more details but partially.

2.2. The 2030 Agenda for Sustainable Development and the status of recent progress

On the 25th of September 2015 in New York, the General Assembly of the United Nations adopted 17 SDGs and 169 targets to be achieved by 2030 (or earlier in the case of particular targets) as an extended continuation of and a supplement to the Millennium Development Goals, which demonstrated remarkable but uneven progress. Due to the recognition of the necessity of a system-level approach and the inherent repercussions, the inseparability of the economic, social, and environmental dimensions prevails in formulating the specific objectives. The concept rests on five pillars: people, planet, prosperity, peace, and partnership. The SDGs and their targets serve as a guideline for elaborating sustainable development policies at the national, regional, and global levels. Indicators have been constructed for measuring progress. (*United Nations, 2015, pp. 1-2, 5-7, 12*) Table 3 recapitulates the headings of the SDGs. Table 24 of the Appendix provides a brief overview of their targets and indicates earlier target dates than 2030.

3. Table: The SDGs

Index	Denomination of the SDG (*United Nations, 2015, p. 14*)
1	Ending poverty
2	Achieving food security, improved nutrition, and sustainable agriculture by eradicating hunger
3	Health and well-being
4	Inclusive and equitable quality education and lifelong learning
5	Gender equality
6	Water and sanitation
7	Clean and affordable energy
8	Sustainable economic growth and decent work
9	Sustainable infrastructure and industrialisation and fostering innovation
10	Moderating national and international inequalities
11	Inclusive and sustainable settlements
12	Sustainable consumption and production patterns
13	Tackling climate change
14	Sustainable use of marine resources
15	Sustainable use of terrestrial ecosystems
16	Peaceful and inclusive societies
17	Global Partnership for Sustainable Development

In accordance with the vision of the founders, the SDGs flash the silhouettes of a new prosperous era and enable mankind to create a world reminding us of entopias (realisable worlds by bringing reality and desires together) through a profound transformation. (*Hideg et al., 1999, pp. 10-11)*

The evaluation of the status of 2023 pointed out that the SDGs are off track by demonstrating uneven progress within and between countries. There is still a burning need for reforming global finance in order to overcome the financing constraints related to the SDGs in the case of developing countries. Similarly, one of the priority areas is mobilising novel financial means within the European Union (EU) to fund the required transformation as resources were diverted into responding to recent multiple crises. Hungary occupied the 22nd place (out of 166) based on the 2023 SDG Index ranking. (*Lafortune et al., 2024, pp. 7-8; Sachs et al., 2023, pp. 4, 13, 25-26*) Table 4 reveals a more sombre position for Hungary in terms of health.

4. Table: Levels and trends of selected SDGs (2023)
(Sachs et al., 2023, pp. 36-37)

Countries	Health and well-being (3rd)	Tackling climate change (13th)
High-income countries (HIC)	challenges remained	major challenges remained
	moderately increasing trend	stagnating trend
Hungary (HU)	significant challenges remained	major challenges remained
	moderately increasing trend	stagnating trend

According to the last performance, Table 5 collects the relevant indicators representing the weakest or most vulnerable, risky fields to be dealt with in Hungary. Again, comparative values work as a benchmark.

5. Table: Relevant indicators and their status
(*Sachs et al., 2023, pp. 271, 531*)

Indicator	Value (year), rating, and trend
Prevalence of obesity[5] within the adult population	HU: 26.4%, HIC: 24.9% (2016), HU: major challenges remained with a worsening trend
Age-standardised death rate due to cardiovascular disease, cancer, diabetes, or chronic respiratory disease in adults aged 30–70 years	HU: 22.1%, HIC: 11.9% (2019), HU: significant challenges remained with a stagnating trend
Per capita CO_2 emissions from fossil fuel combustion and cement production	HU: 5.0 t, HIC: 10.2 t (2021), HU: major challenges remained with a worsening trend
Per capita CO_2 emissions embodied in imports	HU: 1.8 t, HIC: 2.5 t (2018), HU: major challenges remained with a worsening trend

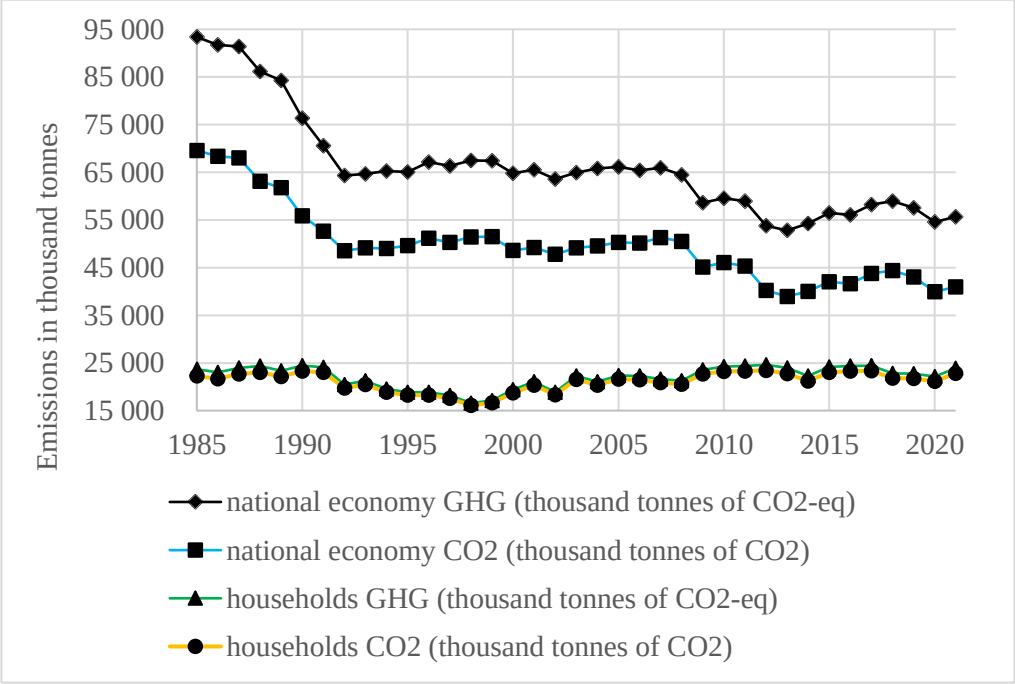
In order to make greater strides in the areas where Hungary falls backwards (e.g. obesity within the adult population, mortality due to cardiovascular disease, CO_2 emissions from fossil fuel combustion) the articles put forward ideas for raising awareness and applying further measures.

[5] BMI≥30 where BMI=weight in kilograms/(height in meters)^2 [kg/m^2]

2.3. Greenhouse gas emissions in Hungary

This subchapter evaluates the period between 1985 and 2021 in Hungary, by focusing on the economy. As Figure 2 shows, both the GHG and CO_2 emissions of the households remained in 2021 amidst temporary ameliorations slightly above the levels of 1985. Despite the steep decline in emissions in the late 1980s, the early 1990s, and 2009, the latest emission levels of the national economy hint at the need for deep decarbonisation by reducing the carbon intensity in order to attain carbon neutrality at the latest in 2050. The major industries causing the difference between GHG and CO_2 emissions and their respective shares are (i) agriculture, forestry, and fishing (50.0%), (ii) water supply; sewerage, waste management, and remediation activities (26.0%), (iii) electricity, gas, steam, and air conditioning supply (10.5%), (iv) wholesale and retail trade, repair of motor vehicles and motorcycles (3.6%), (v) manufacturing (3.2%), and (vi) mining and quarrying (3.0%). (*HCSO, 2023a*)

2. Figure: GHG and CO_2 emissions of the Hungarian national economy and households[6] (1985–2021) *(HCSO, 2023a)*



Note: regime change (1989–1991), joining the EU (2004), Kyoto I/EU ETS II (2008–2012), Kyoto II/EU ETS III (2013–2020)

[6] The sum of the emissions stemming from the national economy and those of households deviates from the total emissions of air pollutants as reported to UNFCCC (United Nations Framework Convention on Climate Change).

The brief history of the last three decades, divided into two epochs, helps in understanding the economic-social-political context. (*Hübner, 2019, pp. 185-207*)

1st phase (economic-political transition to a free market democracy, enlargement of the EU, 1989–2004):

The proclamation of the Third Republic on the 23rd of October 1989 and the dissolution of the Council for Mutual Economic Assistance on the 28th of June 1991 gave impetus for radical political, social, and economic transformation by introducing a market economy instead of the former centrally planned economy. After the collapse of the Eastern Bloc, the EU became the major trading partner and Hungary implemented the Acquis Communautaire of the supranational union. The economic and political integration process culminated in the Treaty of Accession signed in 2003 in Athens and entered into force on the 1st of May 2004. The temporary economic downturn (see massive deindustrialisation and sectoral change) resulted in a substantial reduction in emissions. However, less impact can be perceived regarding environmental policies and green innovations. Due to the lack of developed ecological culture, environmental issues were primarily triggered by EU initiatives and Western civil society organisations. Thanks to the low wages, the qualified workforce, and the good quality of higher education, the influx of foreign direct investments (FDIs) in the manufacturing and the service sector provided the required capital, production methods, technologies, and industrial relations practices for modernisation. The transition enabled national companies to integrate their production into the global supply chains of transnational corporations (TNCs). Nevertheless, the necessary innovation regime for both pervasive technology transfers and effective collaboration between public scientific institutions and business enterprises was not ensured. In addition, the vulnerability of the selected country and the primacy of the interests of TNCs represent the seamy side of the dependence on FDIs.

2nd phase (designing the decarbonisation pathway under the influence of external actors, 2005–2021):

Under the Kyoto Protocol (signed in 1997, effective from 2005), Hungary committed itself to generous binding targets: a 6% reduction in GHG emissions for the period 2008–2012 compared to the average emission levels of the years 1985–1987 (note: EU-15 as a whole set an 8% cut by applying 1990 as basis year for the same period). For the next phase (2013–2020), national emission limitations were replaced by a single EU-

wide cap imposing a 20% decrease in GHG emissions by relying on the base year levels of 1990. For the consecutive decade, the EU envisages cutting back emissions by at least 55% (after updating the previous target of 40%) by 2030 compared to 1990. The level of carbon intensity in Hungary is similar to the EU average. The milestones of the Hungarian low carbon trajectory are enacted into the Climate Protection Act (2020, XLIV) by designating 2050 as the target year for obtaining complete carbon neutrality in accordance with the European Green Deal, see more details in Section 2.4. (*EC, 2023a*)

The main ongoing government instruments are composed of increasing energy savings and efficiency in order to release the considerable general energy efficiency potential. Regarding power supply, preserving the prominent role of nuclear energy in generating electricity (Paks II project), augmenting the share of renewable energy (special focus on biomass accounting for 68% of the quantity of energy produced from primary renewable energy sources and waste in 2020), and utilising the waning domestic coal and lignite resources (below 3% of primary energy use in 2021) in a more eco-friendly manner can be highlighted. Modernising district heating systems, enhancing storage capacity, developing new supply routes, attracting investments in energy-sensitive sectors, constructing cross-border capacities, and integrating the Central European grid network are also part of this concept. The trends that strongly influence the main processes on the energy market are electrification, sector coupling, decarbonisation, decentralisation, and digitalisation. (*HCSO e-Shelf, 2022, Tables 4.5.1, 4.5.7; MIT, 2020b, p. 213*)

Economic catch-up considerations and short-term policy attitudes of the elites can be adduced as motivators. Commitment is still rather generated abroad, national innovation and environmental policies are moulded by EU programmes and regulations. The energy balance heavily rests on imports from natural gas, petroleum, and petroleum products, and to a lesser extent from electricity, thus, regional cooperation is crucial for energy security in the sense of uninterrupted availability. Last but not least, the reforestation programme was successful as it augmented the stocked forest area by more than 10% compared to 2000, furthermore, the forest strategy envisages a proportion of 27% of the country's territory (in 2021, 20%) until 2050 by planting trees on 680 thousand hectares as a carbon sink. (*HCSO e-Shelf, 2022, Table 6.3; MA, 2016, p. 48*)

Hungary belongs to the country group with very high human development and demonstrates a favourable value for CO_2 emissions per capita arising from production.

This member of the Visegrád Four has all the relevant makings for becoming one of the climate forerunners. Almost ¾ of the domestic total emission of GHGs stemmed in 2021 from the national economy, consequently, mobilising enterprises for climate issues can cut back these emissions. In spite of starting from an advantageous point, Hungary has to make severe efforts to lower its CO_2 emissions as the share of fossil fuels (oil, natural gas, and coal) was still close to 70% of primary energy use in 2021. In contrast, the complement, i.e. the carbon-neutral share (nuclear energy, hydroelectricity, solar, wind, biofuels, geothermal, biomass, and other carbon-neutral sources), surmounted the threshold of 70% in the cases of Norway and Sweden. (*BP, 2022; HCSO e-Shelf, 2022, Table 4.5.2; HCSO, 2023a; UNDP, 2022, p. 299*)

Despite low levels of environmental protection and consciousness coupled with commensurate carbon dioxide emissions per unit of GDP, technological conditions are ensured for abating air pollution. For instance, by focusing on the production of cement, steel, ammonia (NH_3), and ethylene (C_2H_4), the report of *McKinsey & Company* (2020, pp. 7, 25-26, 52) proposes effective decarbonisation tools, a subset of the toolkit of eliminating air pollution. These are (i) demand-side measures through fewer primary resources (increased circularity) and (ii) energy efficiency improvement, which can result in lower energy use per produced volume. In addition, (iii) renewable energy sources can enable us to electrify heat, (iv) hydrogen can function as fuel or feedstock, and (v) biomass can be utilised to replace fuel or feedstock. (vi) Carbon capture (Carbon Capture and Storage, Carbon Capture and Utilisation) and (vii) other innovations (e.g. innovative processes or alternative feedstock) complete the list. Compared to the business-as-usual scenario, the decarbonisation of the industry – in the case of the four enumerated sectors – requires a fourfold-ninefold increase in the use of electricity from carbon-neutral sources for power and hydrogen consumption.

In the spirit of decarbonisation, the second article undertook the quest to establish a narrow relation between competitiveness and both environmental protection and digitalisation in the case of SMEs, whereas the third article makes suggestions on how to conceive targeted approaches when raising awareness in the circle of retail customers depending on their level of environmental awareness. The fourth article endeavours to promote the spread of PV microinstallations, while the central topic of the fifth study is environmentally friendly mobility.

2.4. National legislation, strategies, and main institutions of environmental protection

Without any claim of completeness, this subchapter attempts to collect the major legislative sources (acts and decrees), plans, strategies, and the involved institutions in connection with environmental protection.

Until 2010, a separate environmental ministry with a dedicated apparatus operated in the administration (see the **Act on listing the ministries of the Republic of Hungary 2006, LV**). In 2010, the **Act on listing the ministries of the Republic of Hungary 2010, XLII** dissolved the former Ministry of Environment and Water Affairs and created the Ministry of Rural Development by assigning the responsibilities of the former organ to the latter. The successors are the Ministry of Agriculture (2014–2018) and the Agrarian Ministry (2018–2022). As of the beginning of 2024, environmental protection is still integrated into the Government as part of other ministries. Subareas have splintered off from environmental protection: nature conservation, the coordination of the national park directorates, forest and wildlife management, and land affairs burden the Agrarian Ministry, while environmental affairs, the transition towards a circular economy, energy and climate policy, waste management, and the sector of water utilities fall within the competence of the Ministry of Energy. The Ministry of Interior coordinates the water administration bodies: the General Directorate of Water Management and its 12 local water directorates. Currently, the regional environmental protection authorities are subordinate to the government offices under the direction of the Ministry of Public Administration and Regional Development. (*GDWM, 2024; ME, 2024; NLD, 2023a-2023e, 2024a*)

Safeguarding the natural heritage and environmental values was set up under the auspices of the **Act on the general rules of environmental protection 1995, LIII**. The planning of environmental protection is based on the National Environmental Protection Programme which is approved by the Parliament following legislative cycles lasting 6 years (paragraph 40). Comprehensive environmental protection plans (ranging from the municipality to the country level) form part of the Programme. As listed in paragraph 48/B (2), they incorporate:

(i) a situation assessment of the environment and its main influencing factors;

(ii) the environmental protection targets that are concordant with sustainable development;

(iii) the main measures to be taken in order to achieve the targets and the schedule for their implementation;

(iv) tools for regulating, controlling, and evaluating the realisation of the targets, and

(v) the expected cost of both the fulfilment of the measures and the use of the tools according to point (iv) by indicating their planned financial resources. (*NLD, 2024b*)

The **Decree of the Ministry of Environmental Protection and Rural Development on the conditions for the use of the ecolabelling 1997, 29 (29th of August)** aims at spreading products with more favourable environmental properties underpinned by a life cycle assessment and as a consequence developing environmental awareness by means of information and motivation. The Hungarian National Ecolabel is symbolised by the Hungarian Cedar. The Hungarian Ecolabelling Organisation coordinates the operation of the certification system. The Evaluation and Qualifying Committee decides on the criteria of the Hungarian National Ecolabel scheme upon the recommendation of the Organisation. (*NLD, 2024c*)

The **Act 2011, CXI** enacted the institution of the **Commissioner for Fundamental Rights of Hungary**. The entitlements of the deputy commissioner (ombudsman) who is responsible for the protection of the interests of future generations are laid down in paragraph 3. In the circle of his competence as the spokesperson of future generations, he possesses the right to provide information about his experiences in enforcing the interests of future generations, drawing attention to the danger of infringement, recommending the initiation of ex officio proceedings or referring to the Constitutional Court, participating in investigations, monitoring the implementation of the strategy of sustainable development adopted by the Parliament, proposing the creation and amendment of legislation, promoting the presentation of the values of the domestic institutional system through international activities. (*NLD, 2024d*)

The **Act on waste 2012, CLXXXV** indicates multiple purposes in its preamble, amongst others, improving the efficiency of resource use, ensuring long-term competitiveness, and from 2021, accelerating the transition towards a circular economy as well. It stipulates the obligations of both manufacturers and distributors and the basic

requirements of the extended producer responsibility system. On the 1st of July 2023, waste management was transferred to the exclusive responsibility of the state. The law sets out the sectoral rules to be applied to the waste management concession system e.g. specific provisions related to ensuring the continuous supply of waste management public service and those regulating the concession fee for financing the system. Government decrees provide more regulations related to specific waste types. (*NLD, 2024e*)

The scope of the **Act on road transport 1988, I** expands to the operation of electric charging equipment, electromobility services, electromobility users, and electric vehicle dealers. It includes the basic rules for the electric charging equipment and electromobility services. (*NLD, 2024f*)

The **Act on consumer protection 1997, CLV** was amended according to the principles of circular economy. Paragraph 16 contains the specific rules of responsibility in order to prevent waste generation from the side of the triad of manufacturers, distributors, and consumers. Additionally, manufacturers and distributors are required to strive:

(i) to exclude the planned obsolescence, to ensure the identical lifetime of subassemblies and components, the product's ability to be both developed and supplemented, and the modular nature of its subassemblies;

(ii) to provide spare parts and a repair network;

(iii) to ensure the use of recycled materials and the recyclability of products;

(iv) to bear obligations related to the lifetime of digital and connected devices and the obsolescence of software;

(v) to reduce risks due to the obsolescence of the operating system delivered at the time of the purchase of products and that of software related to software updates, and

(vi) to inform consumers about the aforementioned measures. (*NLD, 2024g*)

The **Act on district heating services 2005, XVIII**, the **Act on electricity 2007, LXXXVI**, and the **Act on natural gas supply 2008, XL** guided by encouraging energy efficiency and energy savings, deal with renewable energy sources (for the first two laws: wind, solar, water, aerothermal, geothermal, hydrothermal energy, biomass, energy obtained from biogas /combustible gases produced in landfills and wastewater treatment facilities, as well as from other organic materials/, while gases originating from biomass or biogas can be considered as natural gas). (*NLD, 2024h-2024j*)

Paragraph 2 of the **Act on the promotion of the use of renewable energy for transport purposes and on the reduction of greenhouse gas emissions 2010, CXVII** sets the target share of renewable energy sources of the final energy consumption used for transport purposes in 2030 to 14%. The sustainability requirements for liquid bioenergy carriers, biofuels, fuels produced from biomass, as well as intermediate products and their raw materials are set out in section 3. (*NLD, 2024k*)

The **Act on the environmental protection fee 2011, LXXXV** was constituted to create financial resources for the prevention and reduction of damages and to facilitate the fulfilment of environmental protection standards. Batteries, packaging materials, other petroleum products, other plastic products, other chemical products, electrical and electronic equipment, tyres, office paper, and paper for advertising print are subject to an environmental protection fee as stated in paragraph 1 (3) and as listed their fee items in annexe 2 to the act. (*NLD, 2024l*)

As of the 1st of July, 2021, the **Government Decree restricting the placing on the market of certain single-use and certain other plastic products**[7] **2021, 301 (1st of June)** banned the concerned plastic products with the purpose of reducing their impact on the environment. (*NLD, 2024m*)

The **Government Decree on the detailed rules for the operation of the extended producer responsibility system 2023, 80 (14th of March)** stipulates the obligations related to extended producer responsibility, launches the extended producer responsibility fee and the obligation to pay it, determines the amount of the fee, and imposes the obligation to register and provide data regarding circular products. (*NLD, 2024n*)

The goal of the **Government Decree on the detailed rules of the financial guarantee, provisions, and environmental protection insurance related to waste management 2023, 681 (29th of December**) is to ensure financial means for the elimination of environmental damages and recultivation by indicating the calculation method of the required amounts. (*NLD, 2024o*)

The **Act on the rules of corporate social responsibility, which also take into account environmental, social, and welfare aspects, which serve to encourage sustainable financing and unified corporate responsibility, and on the amendment of other related laws 2023, CVIII** contributes to more transparency in terms of

[7] e.g. oxo-degradable plastic

sustainability by means of data disclosure about environmental, social, and corporate governance (ESG) issues in ESG reports. (*NLD, 2024p*)

In line with the European Green Deal of the EU, the **Act on climate protection 2020, XLIV** lays down the milestones of the decarbonisation pathway in paragraph 3 by formulating four objectives:

(i) The emission of GHGs will be decreased by at least 40% by 2030 compared to the level of 1990.

(ii) After 2030, the increment exceeding the final energy use of the level of 2005 may be ensured solely from carbon-neutral energy sources.

(iii) The country envisages a share of at least 21% from renewable energy sources regarding gross final energy consumption by 2030.

(iv) By applying carbon capture for the remaining GHG emissions, the target year for achieving complete climate neutrality is 2050. (*NLD, 2023f*)

According to paragraph 4, the Government effectuates related activities in six domains:

(i) It sets out the required measures for attaining the indicated share of renewable energy sources by 2030.

(ii) and (iii) It elaborates the subsidisation of inhabitants and local communities in transforming them from consumers into active energy producers as well as of domestic business units concerning their renewable energy and energy efficiency developments.

(iv) It adjusts related public policies (e.g. in the field of transport, energy, and waste management) on the basis of sustainability aspects.

(v) It develops support programmes encouraging climate protection technologies.

(vi) It creates financial resources for developments promoting climate protection by issuing green bonds and pursuing campaigns raising awareness with particular regard to economic decision-makers. (*NLD, 2023f*)

The corresponding legislative sources are complemented with plans and strategies of a more elaborated level. Their digest – incl. strategies related to health – is given below (the closing year of the time horizon is indicated in parentheses):

1. National Energy and Climate Plan (2050): Its objectives, policies, and measures can be grouped along five dimensions: (i) decarbonisation, (ii) energy

efficiency, (iii) energy security, (iv) internal energy market, and (v) research, innovation, and competitiveness. (*NECP, 2023, p. 23*)

2. Second National Climate Change Strategy (2030, with a view to 2050): It includes a decarbonisation roadmap, an adaptation strategy, and an awareness raising plan relying on a partnership demonstrating a broad range of stakeholders. (*NLD, 2024q, p. 11*)
3. National Energy Strategy (2030): By spreading the use of renewable energy sources and alternative modes, its scope covers (i) energy efficiency, (ii) electricity production, (iii) heat production, and (iv) transport in order to accomplish the energy structure change towards a low CO_2 intensity state in 2030. (*NLD, 2024r, p. 30213*)
4. National Building Energy Strategy (2030): It aims at reducing substantially the energy use of the domestic building stock. (*NLD, 2024s*)
5. Long-Term Renovation Strategy (2050): Its operational goals encompass: (i) the reduction in energy consumption of residential buildings, (ii) the abatement of carbon dioxide emissions related to the energy use of buildings, and (iii) the augmentation of the ratio of zero-energy buildings. (*MIT, 2020c, p. 7*)
6. National Clean Development Strategy (2050): It designates the main areas of intervention: (i) residential energy saving, (ii) energy efficiency, (iii) the electrification of the economy, (iv) Carbon Capture, Utilisation, and Storage (CCUS), (v) hydrogen technology, (vi) industrial processes and product use, (vii) second generation (or advanced) biofuels, (viii) agriculture and Land Use, Land-Use Change, and Forestry (LULUCF), (ix) waste sector, (x) research and development and innovation, and (xi) education and training. (*MIT, 2021a, pp. 13-14*)
7. National Forest Strategy (2030): The document deals with the challenges affecting forests and forest management. The strategic planning was determined by the following comprehensive directions: (i) rural development, (ii) state and private forest management, (iii) nature conservation, forest protection, wildlife management, and forest use, (iv) administration, (v) research and education, and (vi) communication. (*MA, 2016, pp. 9, 16*)

8. National Waste Management Plan (2027): The transition towards the circular economy – by (i) increasing recycling for all waste streams, (ii) reducing the disposal of waste by landfilling, and (iii) preventing the generation of waste – can raise the Hungarian waste management sector amongst the best in Europe on the mid-term. (*MIT, 2021b, p. 295*)
9. Digital Success Programme (continuous): It addresses the digital transformation of Hungary. The subareas with a separate specific strategy are (i) digital child protection, (ii) digital export development, (iii) digital education, (iv) digital start-ups, (v) digital agriculture and food industry, and (vi) artificial intelligence. (*DSP, 2024; NLD, 2024t*)
10. National Digitalisation Strategy (2030): Its four pillars consist of (i) a digital infrastructure supporting the development of the digital ecosystem, (ii) digital competences (target groups are individuals, employees, and ICT specialists), (iii) the digital economy (digital transformation of businesses in general, furthermore SMEs – startups in particular – operating in the ICT sector, the data economy), and (iv) e-government (digital public services for both citizens and businesses, cross-border services, and their support). (*PMCO, 2021, p. 8*)
11. National Transport Infrastructure Development Strategy (2050): Its main objectives are (i) creating a more socially useful transport structure concerning both passenger and goods transport (e.g. public transport, non-motorised modes) and (ii) increasing the quality and efficiency of transport services (e.g. improving transport infrastructure). (*MND, 2014, pp. 8-9*)
12. Ányos Jedlik Plan 2.0 (2030): The priority areas of electromobility are: (i) market model, (ii) charging infrastructure, (iii) subsidies for electric vehicles, (iv) government and municipal charging stations and electric car fleet, (v) decarbonisation in public transport (e.g. electric buses, carsharing), (vi) municipal energy production and smart network solutions, (vii) national standards for local smart networks, (viii) cost reduction of charging energy, and (ix) socialisation of electromobility. (*MIT, 2019, pp. 14-19*)
13. Plan Irinyi (2020 and thereafter): It determines the directions of innovative industrial development within the framework of reindustrialisation. The tools can be assigned to five categories: (i) application of new or digital technologies,

(ii) energy- and material-efficient tools and production methods, (iii) mitigating territorial inequalities, (iv) expanding employment, job creation, and (v) more efficient use of resources. (*MNE, 2016, p. 71*)

14. Fifth National Environmental Protection Programme (2026): It identifies four central domains: (i) human health and quality of life, (ii) natural values and resources, (iii) resource saving and efficiency, green transition, and circular economy, and (iv) environmental safety. (*NLD, 2022, pp. 60-61*)
15. Research, Development, and Innovation Strategy (2030): Its vision is a knowledge-based and sustainable economy and society that create high added value by embedding research, development, and innovation buttressed by production, flow, and use of knowledge. (*MIT, 2021c, pp. 23-24*)
16. National Smart Specialisation Strategy (2027): It denotes eight priority areas of the national economy: (i) agriculture, food industry, (ii) health, (iii) digitalisation of the economy, (iv) creative industry, (v) resource-efficient economy, (vi) energy, climate, (vii) services, and (viii) cutting-edge technologies. In addition, two horizontal priorities are set: (i) innovation of the public sphere and universities, and (ii) training and education. (*NRDIO, 2021, p. 50*)
17. Strategy for strengthening Hungarian micro, small, and medium-sized enterprises (2030): The five pillars are composed of: (i) increasing competitiveness through knowledge transfer, technology change, digital and sustainable operations, well-trained workforce, and internationalisation, (ii) entrepreneur-friendly business and tax environment, (iii) financing, (iv) technologies of the future and innovation as breaking points, and (v) knowledge, entrepreneurial culture, and generational change. (*MIT, 2023, pp. 45, 75, 87, 102, 118*)
18. Healthy Hungary (2027): This strategy formulates its objectives in seven territories: (i) public health (incl. the reduction of circulatory and cancer diseases and premature death), (ii) basic care, (iii) outpatient and inpatient specialist care, (iv) human resources working in health care, (v) digital health, (vi) pharmaceutical strategy, and (vii) health science activities. (*MHR, 2021, pp. 66-88*)

19. National Health Informatics Strategy (2030[8]): It envisages that the Hungarian health care system effectively uses the tools of informatics, digitalisation, and artificial intelligence. (*NLD, 2024u*)

Apart from strategic documents, construing the succinct paragraph 4 of the Act on climate protection elucidates that it stipulates merely cornerstones by leaving ample room for manoeuvre for creating business-social acceptance, support, and commitment, and thus by offering numerous research opportunities, e.g. how to conceive targeted approaches when raising awareness (see the third article) or how to bolster the penetration of photovoltaic (PV) technology in the circle of retail customers (see the fourth study) or that of electromobility (see the fifth study).

2.5. The landscape of SMEs in Hungary and experiences gained in OECD countries

This subchapter aims to provide an understanding of the diffusion of SMEs in Hungary and the prevailing phenomena that affected them during the Coronavirus disease (COVID-19) pandemic and the recovery in OECD countries.

Paragraph 3 of the **Act on small and medium-sized enterprises and the support of their development 2004, XXXIV** categorises SMEs in Hungary. The logical conditions /uniformly A∧(B∨C)/ related to the typification are shown in Table 6. (*NLD, 2024v*)

6. Table: Requirements of micro-, small, and medium-sized enterprises (*NLD, 2024v*)

Enterprise size class	Number of persons employed	Logical operator	Annual net turnover [10^6 EUR]	Logical operator	Total assets [10^6 EUR]
Micro	less than 10	AND	(max. 2	OR	max. 2)
Small	less than 50	AND	(max. 10	OR	max. 10)
Medium-sized	less than 250	AND	(max. 50	OR	max. 43)
An additional requirement irrespective of the enterprise size class: Apart from investors qualifying as partner businesses, based on capital or voting rights, the direct or indirect ownership share of the state or local government both individually and collectively must be less than 25%.					

[8] assumed target year

In 2022, the predominance of microenterprises (accounting for 95.1% of the total number of enterprises) characterises the Hungarian economy, while the share of SMEs is 3.6% and 0.6% respectively. Albeit 67.4% of the total number of persons employed work at SMEs (incl. microenterprises), they face limitations coupled with harvesting the potential advantages arising from economies of scale. By applying a complementary approach, 64.6% of the total net turnover can be assigned to enterprises not classified as SMEs. Being more actively present in export markets due to the noticeable comparative advantages of larger companies manifests itself in turnover from export sales as well (87.7%). Furthermore, the increasing size of business enables them to create more value added (56.1%) and invest in new tangible assets (68.6%). Table 7 highlights more details. (*HCSO, 2023b*)

7. Table: Distribution of selected indicators by size class in 2022
(*HCSO, 2023b*)

Enterprise size class	Number of enterprises	Number of persons employed	Net turnover	Turnover from export sales	Value added	Investment value of new tangible assets
Micro with 0 employee	4.2%	-	0.2%	0.0%	0.2%	1.1%
Micro with 1 employee	70.8%	20.6%	3.0%	0.4%	5.1%	1.4%
Micro with 2-9 employees	20.1%	19.6%	7.5%	0.7%	10.4%	2.8%
Small	3.6%	16.4%	11.8%	3.2%	14.7%	9.3%
Medium-sized	0.6%	10.8%	12.9%	8.0%	13.5%	16.9%
Not classified as SMEs	0.7%	32.6%	64.6%	87.7%	56.1%	68.6%
Total	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*

Two selected OECD publications offer profound insights from a broader international perspective into the digital agenda related to SMEs. (*OECD, 2021a, pp. 13-14, 21, 27, 2021b, pp. 17-19, 35-37, 63-64, 71, 84, 112, 117-137*)

Digital gaps show great variety regarding their consequences. These divides encompass (i) at the firm level: lower productivity, less capability to innovate, facing difficulties when attempting to scale up or to grow further; (ii) at the market level:

hindrances to dissolve technology lock-ins, non-compliance with data protection regulation, or distortions in competition; (iii) at the aggregate level: distinct inequalities amongst people, settlements, and enterprises. The stage when a firm enters the diffusion of digital technology (e.g. innovator or only late majority) can be conclusive for its prospects, benefitting from network effects and complementarities. With regard to the digitalisation of SMEs, based on an alternative classification, three gaps can be identified in spite of the accelerated uptake of digital tools brought on by COVID-19:

1. The gap related to the company size puts smaller firms at a disadvantage. Albeit digital solutions could enable SMEs to optimise business functions, they indicate irrespective of their size cost grounds (e.g. fees charged by online platforms, price of digital technologies) as the major barrier on the digital pathway. The difficulty of integration or the lack of awareness and adequate skills are named as further impediments. Consequently, combining financial and non-financial support and shaping policies holistically are required. However, medium-sized firms could speed up their progress. The diffusion rate of various technologies (e.g. enterprise resource planning, e-commerce, social media, customer relationship management, cloud computing, and big data) depends on the company size in favour of larger enterprises, especially if technologies are more sophisticated or the number of staff matters for implementation. In the circle of SMEs, digital transformation is mostly limited to basic functions such as general administration and marketing functions (communication, advertising, and sales). The areas where company size plays a less relevant role are online sales, social media, electronic invoicing, and online interactions with the government. Up to 70% of SMEs intensified their use of digital technologies in 2020 as a response to the pandemic. SMEs' digital gap can be captured inter alia in the field of digital awareness, technological lock-ins, internal skills, level of data culture, and access to financial resources.
2. Cross-sector dissimilarities in terms of intensity and patterns of digitalisation have widened further. Knowledge-intensive sectors (e.g. ICT, professional, scientific and technical activities) deepened their transition, while low-digital sectors (e.g. accommodation and food services, construction, transport) deployed more moderately the digital opportunities.

3. Differences across countries are narrowing thanks to the crisis. OECD members in Latin America (Mexico, Colombia, and Chile) could work on their digital backwardness. The share of SMEs that increased digitalisation sprung up boldly due to the stringency of containment measures compared to other OECD states.

Social enterprises and social innovations came to the forefront and in the limelight during the pandemic as the inverse relationship between the social economy and economic downturn enabled them to thrive amidst the crisis. Nonetheless, the vast majority of enterprises were unprepared for the rage of COVID-19. As the SME landscape is characterised by definite heterogeneity in firms and their business ecosystem, devising or shaping adequate SME policy is a complex challenge with the purpose of abolishing regulatory barriers, averting market distortions, and facilitating digital transformation at a brisk pace. Drawing conclusions from the lessons learned, the tools for stabilising and reinforcing SMEs' position consist of a broad range of areas:

1. fostering digitalisation by enhancing e-commerce, widening e-government services, applying teleworking and further smart working solutions on a longer-lasting basis, integrating SMEs into innovation and knowledge networks, and establishing connections between SMEs and providers offering digital solutions;
2. reskilling;
3. promoting the transition to a greener and circular economy;
4. addressing financing issues by means of overcoming liquidity constraints, providing innovation and growth capital, subsidising investments in digitalisation, opening new funding flows, bolstering sustainable finance, building environmental, social, and governance aspects in investment plans and reporting, then, disclosing them;
5. applying a multi-stakeholder approach when ensuring diverse forms of support (government package, targeted initiatives from the private sector, role of the digital industry in offering services, support schemes, and assistance, e.g. free access to learning platforms);
6. establishing a flourishing regional innovation environment by relying on symbiotic links between business, science, and government (digital transformation occurs in this interconnectivity);
7. improving digital security and the digital infrastructure, dealing with risks and vulnerabilities revealed by accelerated digitalisation, and mitigating the digital gaps as

SMEs, which have insufficient internal capacities and low financial resources, have limited access to the digital infrastructure, face low interoperability between systems, are not familiar with liabilities and responsibilities associated with the digital transformation, may run risks of reputation damage, ask for advice, make use of external systems, purchase digital solutions from external sources, and need support even if SMEs are not getting caught in the cross hairs of cyberattacks concerning their digital intensities, volumes and value of data, and intellectual property;

8. diminishing the risks coupled with disruptions in supply chains following a top-down approach and benefitting from the reconfigurations in global value chains by ascending to higher levels of integration (bottom-up approach).

COVID-19 exercised its impacts on the SME sector in such a way that (i) it hampered firm creation and precipitated firm exits, (ii) it forced SME policy responses to COVID-19, and (iii) deepening stringency of containment and social distancing measures entailed an enhancing use of digital technologies. Smaller firms have been severely hit by the pandemic. The size of the sector in terms of employment and value added, economic exposure to lockdowns, risks coupled with business disruptions, and dependence on cross-border value chains determined the structural vulnerability of the sector. Nevertheless, resilience can be improved in four areas:

1. When offline distribution channels fall out and further lockdown measures are employed, market actors move their operations to online platforms by adjusting or redefining their business models. Digital readiness establishes internal capacities for selling online. It is represented by four technologies: (i) high-speed broadband connection, (ii) social media, (iii) e-commerce, and (iv) cloud computing. Social media and e-commerce are a digital springboard for SMEs, while cloud computing services enhance the IT capacity of SMEs and provide digital solutions for them at low costs. Small firms in Hungary are lagging behind in each of these fields.
2. Cash reserves and the government's liquidity support can enable SMEs to maintain operations in the case of liquidity shortages.
3. Simplifying regulations and amending them after evaluation, retrenching the cost of founding a new business, alleviating the administrative burdens on start-ups, softening the strength of the insolvency framework, and reducing the cost of resolving insolvency can create a supportive entrepreneurship regulatory framework.

4. In a changing world, innovation skills rise in value. With particular reference to Hungary, the country ranks in the top 5 OECD members regarding (i) computer and electronics skills and (ii) complex problem-solving. The performance is around the OECD median when evaluating both (iii) adaptability/flexibility skills and (iv) practical intelligence for innovation. (v) Starting a business as the sole investigated weakness falls below the OECD median. (*OECD, 2021b, pp. 149-153, 202*)

In order to promote the prospect of more inclusive growth in the circle of SMEs operating in Hungary, the second article made its recommendations on the fronts of digitalisation and environmental protection. SMEs lagging behind can leverage the transformative potential for deepening both digitalisation and environmental protection in the form of enhanced corporate competitiveness. In addition, corporate well-being programmes (the topic of the first study) can contribute to their better performance. The last three articles enable SMEs that offer environmentally friendly products and services, operate in the fields of renewable energy technologies and green mobility to improve their sales figures and attract new clientele.

2.6. State of environmental consciousness with a focus on Hungary

A) Environmental protection at the level of the national economy and society:

Based on the CO_2 emissions per unit of GDP[9], Switzerland and Sweden can be considered as best performers. Both countries demonstrated the floor of the indicator in 2020 (0.06 kg CO_2 per 2010 USD of GDP), while both Hungary and Germany (one of the climate champions) produced more than double: 0.14 kg CO_2 per 2010 USD of GDP respectively. (*UNECE, 2024*) In addition, see further indicators in Tables 5 and 8. The latter lists figures hinting at unsustainable, less conscious or rudimentary processes in the field of consumption.

8. Table: Indicators related to consumption

Denomination	Hungary	Germany
Organic agricultural area per capita (2021) (*Eurostat, 2023*)	0.03 ha=302.4 m^2	0.02 ha=192.5 m^2
Estimated ecological footprint per person (2022) (*GFN, 2023a*)	3.8 gha	4.5 gha

[9] CO_2 emissions expressed in kilograms per unit of gross domestic product (GDP) in constant 2010 US dollars.

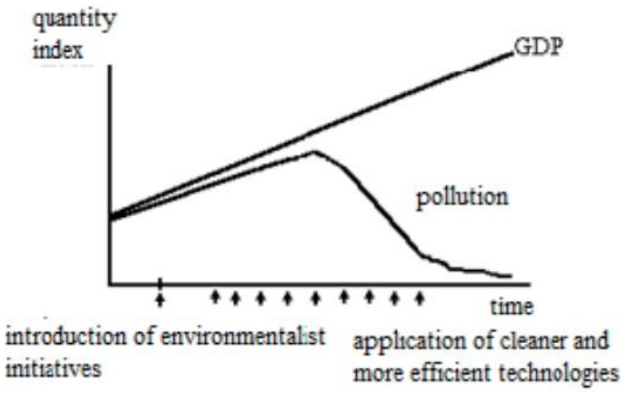
Denomination	Hungary	Germany
Estimated biocapacity per person (2022) (*GFN, 2023a*)	2.6 gha	1.6 gha
Country overshoot day (2023) (*GFN, 2023b*)	30th of May (equivalent to 2.4 Earths)	4th of May (equivalent to 3.0 Earths)
Annual transported goods per capita[10] (2022)	30.6 t (*HCSO, 2023c, 2023d*)	54.7 t (*HCSO, 2023c; Destatis, 2023a*)
Total GHG emissions per capita (2021) (*Destatis, 2023b*)	6.7 t CO_2-equivalent	9.4 t CO_2-equivalent
Human trophic level[11] (2017) (*Sachs et al., 2023, pp. 251, 271*)	2.4 worsening trend	2.4 worsening trend
Per capita total food waste of private households	65.5 kg (2021) (*NFCSO, 2022*)	78.1 kg (2020) (*HCSO, 2023c; Destatis, 2022*)

Note: gha=global hectare

Albeit the annual food consumption volume per capita varies along income deciles, by assuming that one average egg weighs 60 g, the mean of the estimated annual solid food in 2020 in Hungary was 355 kg per capita with a range between 297 kg and 417 kg. The same figure for liquid food (milk, yoghurt, sour cream, kefir) and non-alcoholic beverages was 223 l per capita with a range between 161 l and 288 l. (*HCSO, 2024a*)

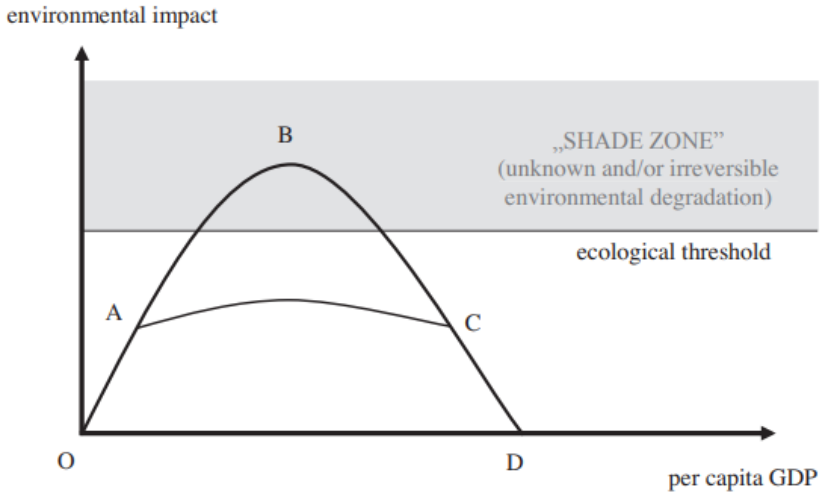
Figures 3 and 4 emphasise the shape of further possible pathways by hinting at trajectories with steeper slopes (Figure 3) and remaining within the ecological threshold (Figure 4). Achieving climate neutrality requires decoupling steady economic growth from GHG emissions (see the objectives of the European Green Deal).

3. Figure: Decoupling of the link between GDP and pollution
(Kerekes et al., 2018, p. 74)



[10] Including export, import, and transit traffic.
[11] The source makes use of the reduced range from 2 (best) to 3 (worst) while theoretically, the trophic level equals 3 when herbivores (e.g. beef or horse) are eaten, and its value is 4 if secondary consumers such as salmon or wild boar are consumed. A shift towards the best value of 2, i.e. becoming primary consumers would be salutary for humanity.

4. Figure: Environmental Kuznets curve
(Kerekes et al., 2018, p. 76)



Returning to the distribution of Hungarian national expenditure on environmental protection, most resources are allocated to wastewater management and waste management. Other environmental protection activities affecting, for instance, the elimination of air pollution are still less prioritised environmental domains (the last available data refer to 2020, *HCSO, 2023e*).

Regarding the potential for digitalisation engaged in abating GHG emissions, the example of Germany can provide tangible data. The country committed itself to a coal- and nuclear-free future energy supply. It has a 14% share of the global market of environmental technologies and resource efficiency, which is far beyond its share amounting to 3% concerning global GDP, in addition, it attempts to preserve its market position and be a paragon of the green transition. In an official report of the government, the forecasted reduction of GHG emissions effectuated by digitalisation is 50 million tonnes of carbon dioxide equivalent for the year 2025, being 5% of the total GHG emissions in 2018. The affected areas are (i) environmentally friendly production, storage, and distribution of energy, (ii) resource efficiency related to energy, feedstock, and material, (iii) sustainable mobility, (iv) circular economy, and (v) sustainable water management. (*BMU, 2018, p. 56; BMWK, 2022, pp. 28, 52; Destatis, 2020*)

By revealing wide discrepancies, Table 9 compares the public energy technology research, development, and demonstration (RD&D) spending between Hungary (low budget, focus on nuclear energy and energy efficiency) and Germany (shifting towards hydrogen and fuel cells as well as renewables) split by technology type. (*IEA, 2023a*)

9. Table: Distribution of public energy technology RD&D spending in 2022 (*IEA, 2023a*)

Technology	Hungary	Germany
Energy efficiency	29.6%	12.3%
Fossil fuels	2.5%	3.0%
Renewables	7.3%	16.5%
Nuclear	42.8%	10.3%
Hydrogen and fuel cells	0.0%	20.7%
Other power and storage technologies	17.3%	7.6%
Other cross-cutting technologies/research	0.5%	8.1%
Unallocated	0.0%	21.4%
Total	100.0%	100.0%
Public RD&D per thousand units of GDP	0.04	0.38
Total budget /million euro (2022 prices and exchange rates)/	6.81	1,486.36
Total budget /million USD (2022 prices and PPP)/	16.34	2,058.67

Note: PPP=purchasing power parity

B) Environmental awareness perceived in the Hungarian population: *Nagy* (2018, pp. 48-53) inquired 442 persons (aged above 18 years) in **2017** in Hungary by making use of questions related to environmentally conscious behaviour. The researcher modified the measurement approach[12] for the assessment of general ecological behaviour of *Kaiser et al.* (1999) in order to conform with the domestic circumstances by creating a scale of pro-environmental behaviour. The statements of the survey can be grouped into six action classes, which follow the next descending order based on their frequency:

1. consuming environmentally friendly products (e.g. opting for more energy-efficient household appliances when purchasing a new one, using paper bags instead of plastic ones),
2. modifying demand in favour of these goods (e.g. buying products made from recycled material or by local producers, renouncing personal car use in urban transport),
3. moderating consumption of traditional products or abstention (e.g. restriction in travelling by aeroplane, wearing an extra layer of clothes to save heating, generating less waste),
4. participating in recycling, selective waste collection (e.g. old batteries, not used pharmaceuticals),

[12] A possible generalised variant (valid in Turkey) for defining and measuring the level of environmental consciousness is represented by classifying individuals by investigating areas such as their approach to and knowledge on environmental subjects, their approach to global environmental problems, their contribution to environmental subjects, providing information about the environment by the hosting unit, and being aware on environmental services of the hosting unit. (*Bostancı, 2019, p. 4*)

5. lodging a complaint or a protest on environmental issues (e.g. refusing products tested on animals or those produced by companies neglecting environmental and social issues),
6. having membership in or donating to an NGO operating in environmental protection.

The author drew two conclusions regarding pro-environmental behaviour:

- its general level can be considered low in Hungary,
- self-assessment of environmentally less aware people exercises a distorting effect and results in a noteworthy greener position compared to the reality irrespective of the level of environmental awareness as shown in Table 10. (*Nagy, 2018, p. 52*)

10. Table: Distribution of respondents along measured and self-reported environmental awareness
(*Nagy, 2018, p. 52*)

Type of awareness	Level of pro-environmental behaviour				
	Very low	Low	Medium	High	Very high
Measured	2.85%	36.10%	46.03%	11.84%	3.18%
Self-reported	0.16%	5.18%	40.02%	46.74%	7.90%

Table 11 summarises the results of the WWF survey conducted in **2019** on a representative sample with the participation of 500 urban inhabitants aged between 18 and 59 years by indicating the percentages of the respondents carrying out or only intending to carry out the respective activity. The gaps in turning intention into action point to noteworthy potential. (*Don't waste it!, 2020*)

11. Table: Share of respondents split by environmental protection activity
(*Don't waste it!, 2020*)

Activity	Action	Intention
Turning lighting off when not in use or unplugging appliances instead of using standby mode	75%	79%
Saving water	65%	80%
Avoiding single-use plastic	59%	74%
Minimising food waste	53%	77%
Recycling	48%	68%
Preferring local products	40%	64%
Buying environmentally friendly products	36%	61%
Making use of public vehicles or bicycles for commuting	28%	59%
Reducing consciously the ecological footprint	22%	61%
Travelling less with own car	18%	54%

A study prepared by the Hungarian National Bank (HNB) in **2022** divided the Hungarian population aged between 25 and 59 years into four segments regarding the relationship between environmental awareness and financial thinking:

(i) 17% are committed to green consumption,

(ii) a further 34% consider environmental protection important if it results in savings,

(iii) the next group – whose share is 16% – is definitely consumption-oriented,

(iv) the final 33% can be described with the attributes 'eco-sceptical' or 'indifferent': in spite of their worse financial status and possible savings, they are not open to partaking in environmental protection. (*HNB, 2022*)

In close analogy with the HNB, *Neulinger* (2022, pp. 9-11) identifies three groups along environmental consciousness:

(i) The first group consists of consumers consciously committed to a sustainable lifestyle, they are better educated, wealthier, and have a higher status.

(ii) The second group also strives for sustainability but contrary to the former group, mainly due to savings reasons. They typically are aged above 40 years, women, and live in small settlements.

(iii) The rest either do not demonstrate any interest towards the climate crisis or even if they accept it, they are not inclined or not able to take action against it.

By investigating the food markets in **2017** in Budapest, five consumer clusters could be identified along aspects such as social characteristics, attitudes (e.g. diet-related health consciousness, environmental consciousness, and price sensitivity), and typical shopping places. The buyers of sustainable products are inclined to pay higher prices, furthermore, they constitute a heterogenous group due to their individual (e.g. health) or collective motives (e.g. environmental sustainability). The five segments are:

(i) green middle class (29%),

(ii) conscious affluent customers (21%),

(iii) customers preferring food directly from the farmer (18%),

(iv) traditional housewives (14%), and

(v) young people of university age (18%). (*Kuslits–Kocsis, 2019, pp. 888-890*)

High price levels can hinder the spread of bioproducts. In **2020**, 83% of the buyers of the largest biomarket of Budapest earned a monthly net income above average. In spite of the fact that compared to traditional food, the price of organic products is typically

higher, almost all respondents of the survey were willing to pay more (average: +61.35%) for ecological products than for conventional ones. (*Kertész–Török, 2021, pp. 141, 148, 150, 152*)

A survey performed in **2022** elucidated that price, taste, and healthiness are the most influencing factors when purchasing products, while neither the place of origin nor sustainability aspects impact in merit consumer decisions. The analysis revealed contradictions in the circle of the participants. First, being aware of less environmental load of a plant-based diet does not necessarily imply the purchase of corresponding products. Second, even if someone considers a plant-based diet healthier, nutrition based on foods of animal origin is preferred due to the assumption that it suits better to the needs of the human body, moreover, it is also more affordable. (*Greenfo.hu, 2022*)

Based on a – in its entirety not representative – sample which involved 997 domestic clients of a sole retail grocery chain in **2022**, the relationship between environmental consciousness and price sensitivity was examined. (*Lányi et al., 2024, pp. 31-33*) Environmental awareness is more important for women. Those under the age of 45 years and in the lowest income group proved to be more price-sensitive than their counterparts along each respective dimension. Four segments could be distinguished depending on the intensity of environmental consciousness and price sensitivity. These are:

(i) Environmentally conscious and not price sensitive (32%): genders are evenly distributed, the proportion of people over the age of 60 years is the largest (23%), the financial status is favourable, 50% possess higher education, and the share of clients living in the smallest settlements is high (5%).

(ii) Environmentally conscious and price-sensitive (37%): the majority (61%) are women, the youngest segment, the proportion of people with a lower income is the highest, 50% possess higher education, and the proportion of residents in the smallest settlements is 4%.

(iii) Not environmentally conscious at all, but price sensitive (20%): this segment has a male majority (56%) and can be described with a higher income, most respondents (34%) are between the ages of 30 and 44 years.

(iv) Not environmentally conscious and not at all price sensitive (11%): equal share of genders, the ratio of members with less income is large, 43% are aged between 45 and 59 years, and 43% have a higher education.

By summing up further research results of the field, demographic aspects such as being women, less aged, more educated, and living in big cities foster the spread of sustainability. (*Lányi et al., 2024, p. 31*)

C) Environmental awareness perceived at the level of Hungarian SMEs:

A survey measuring the competitiveness of Hungarian firms with more than 50 employees was conducted during **2018–2019** by the Competitiveness Research Centre (CRC) of the CUB. 234 enterprises operating in Hungary filled in the questionnaires, thereof 84% small and medium-sized. The typical industries are manufacturing (51%) and trade (24%), the rest are construction, transport and storage, accommodation and food service activities, and information and communication. Almost ¾ of the companies are held by domestic private owners. The aim of the descriptive report (*Chikán et al., 2019, pp. 4-5*) built on the survey is to disclose the determinants of corporate competitiveness and prevailing tendencies. Table 12 encompasses major selected factors contributing to corporate performance and sheds light on the neglected state of environmental protection: its position is amongst the back office functions. (*Chikán et al., 2019, p. 41*)

12. Table: Contribution of activities to the performance of companies (*Chikán et al., 2019, p. 41*) N=222-225 companies

Activity	Significant	Moderate
Production/Services	85%	10%
Sales	83%	12%
Quality management	80%	11%
Logistics	80%	13%
Procurement	79%	18%
Human resource management	78%	16%
Finance	76%	20%
Marketing	70%	13%
Environmental protection	68%	16%
Controlling	68%	22%
ICT	68%	16%
Accounting	64%	20%
Research and development	59%	16%
Corporate Social Responsibility	57%	15%

Table 13 compares the at least indifferent evaluations of the benefits of environmental protection. It turned out that from the four investigated areas (1. the reduction of production costs, 2-4. the improvement of productivity, corporate image, and product im-

age), corporate image, i.e. how the public interprets the company can the most capitalise on environmental protection technological measures. (*Chikán et al., 2019, p. 31*)

13. Table: The effect of environmental protection technological measures by areas (*Chikán et al., 2019, p. 31*) N=216 companies

Area	Favourable	Neutral
Production costs	39%	38%
Productivity	37%	43%
Corporate image	48%	34%
Product image	42%	37%

Scrutinising the outcomes of the impact of environmental protection on financial performance and risks elucidated that, all aspects considered, environmental protection proved to be an efficient tool with triple impacts. First, environmental management can reduce costs, second, differentiating environmentally friendly products can increase income, and third, reducing environmental risks can mitigate general business and financial risks as well. Both internal (reducing environmental risks and enhancing corporate image) and external motives (current severity of regulation and its expected tightening, manifestation of environmental problems, advantages of competitors, and societal pressure) impel SMEs to deepen their environmental protection activities. Interestingly, the competitors and the society are the less important influencers. From the circle of stakeholders, the position of customers, owners, employees, local communities, and authorities is the most decisive in inducing SMEs to protect more actively the environment, in contrast, the role of environmental NGOs and labour unions is moderate. (*Chikán et al., 2019, pp. 32-34*)

Nagy–Diófási-Kovács (2020, pp. 42, 45-46) divided 144 domestic companies from the aforementioned database of the CRC based on their ICT use into clusters characterised by advanced ICT (43 firms, 30% of the sample) or lagging ICT (101 enterprises, 70% of the sample). They stated that there is a positive connection between high-level ICT use and environmental performance based on many indicators, e.g. energy use, recycling, reuse of materials, elimination of hazardous materials, reduction of packaging, environmental accounting, environmental auditing, as well as environmental policy and goal setting. This finding is in accordance with the similarity between the distributions of both environmental protection and ICT arising from the CRC survey (see Table 12).

Promoting the ascent of environmental protection in the hierarchy of corporate activities, allocating more resources to environmental protection and especially to air quality protection, making use of environmental management tools, deploying digitalisation, enhancing research and development expenditure, decreasing energy use intensities coupled with the decarbonisation of the power system may ensure notable advancement on the low carbon pathway and in eradicating air pollution posing public health, welfare, and environmental risks. A slice of these measures is represented by the second article, which designates the areas of both environmental protection and digitalisation improving corporate competitiveness. As the general level of environmentally conscious consumer behaviour can be considered low in Hungary, economic and political decision-makers should take the initiating lead. One of the aims of the third article is to provide proposals on how to heighten the environmental awareness of citizens. Without applying any measurement approach for the assessment of ecological behaviour, the study classifies consumers into clusters based on their environmental awareness. Target 7.2 (building more on renewable energy sources worldwide) inspired the fourth article, whereas target 11.2 (safe transport systems with general access, more emphasis on public transport) provided the research field for the fifth study (see the list of targets in Table 24 in the Appendix). By taking indirect impact into account, the horizon of the 2nd-5th articles ranges from tackling climate change to accomplishing numerous other SDGs (e.g. affordable clean energy, inclusive and sustainable economic growth, innovation, resilient human settlements, and sustainable consumption patterns).

2.7. State of health

One of the eternal desires of mankind is to prolong life as exempt from worries and illnesses as possible. Once, alchemists experimented to invent the elixir of youth in their laboratories and living longer was the prerogative of the rich. Nowadays, obtaining a longer, happier, and healthier life has become a reality for the majority of humanity. While global life expectancy at birth remained below 30 years in 1800, less violence and more effective health care are likely to institutionalise a set of favourable factors enabling a newborn to live almost 94 years in 2100 in the circle of the top performing countries

according to the forecast. Not only life expectancy and its part, i.e. healthy life expectancy are rising, but also in parallel, the inequality of life expectancy amongst citizens within a specific country is falling. Nevertheless, (i) the gender gap (e.g. overweight and obesity, preventable mortality, mortality from treatable causes) in favour of women, (ii) the socio-economic gap divided in this study into (a) education disparities (e.g. mortality from circulatory diseases or cancer, overweight and obesity, daily consumption of fruit and vegetables, non-work-related physical activity) in favour of better educated persons and (b) the economic gap (e.g. chronic diseases or disability in the case of elderly aged 65 years and over, mental health) in favour of wealthier citizens, and (iii) the dissimilarities between country groups (e.g. health indicators, leading causes of deaths, maternal mortality, neonatal mortality, childhood mortality under 5 years of age, child malnutrition, government's health spending, financial hardship caused by out-of-pocket health spending, health system capacities) mostly[13] based on the income level in favour of high-income countries remain worldwide phenomena even if particular gaps may narrow. The demographical trends are deepening unfolding ageing societies by projecting an estimate of at least 50 years for the median age concerning such populous countries like China, Brazil, or Japan. A positive relationship can be identified in each pair below:

(i) between life expectancy and GDP per capita,

(ii) between life expectancy and health care expenditure per capita, and

(iii) between years lived with disability and health care expenditure per capita.

(*OECD/EU, 2022, pp. 96-104, 118-122; OECD iLibrary, 2023; Our World in Data, 2019; WHO, 2022, pp. vii-ix, 24-26, 43, 67-68*)

The best medicine is when you do not need any medicine at all. This saying with its undoubted truth roots in treating the problems primarily through more health consciousness, occupational and road traffic safety, and prevention of further accidents. Correspondingly, individuals have ample opportunity to mitigate major risk factors, which can be classified as detailed below:

1. Modifiable or preventable behavioural risk factors may be averted by means of moderate use of alcohol, renouncing tobacco and illicit drug use, being more active physically, and getting rid of unhealthy diets.

[13] Beyond income, the confluence of other factors engenders that French and Spanish females can enjoy the most favourable mortality rates and consequently the best life expectancies within the EU. (*OECD/EU, 2022, pp. 91, 94*)

2. Metabolic risk factors can be put under control by avoiding overweight or its exacerbation, i.e. obesity, treating raised blood pressure, and normalising levels of glucose and fat in the blood.
3. Environmental risk factors (e.g. fine particulate matter pollution within air pollution) may be subject to prevention as well.

Irrespective of the SDGs, ensuring access to safely managed drinking water, sanitation and basic hygiene services, clean circumstances for cooking, reducing outdoor air pollution below tolerable limitations, and striving to eradicate violence against women are fundamental components of human dignity. With a focus on universal health coverage, improving primary health care, rendering health financing more sustainable with the guarantee of affordability for patients, and tailoring health system capacities to the country-specific needs are at the forefront of health policies. By weakening the pillars of universal health coverage (namely the access to health services, the quality of care, and financial protection), the COVID-19 pandemic threw light on the Achilles heel of the health systems: underdeveloped planning concerning worst-case scenarios. This resulted in unpreparedness and insufficient capacities for shocks like a global epidemic, violating the principle of equal treatment, furthermore, it induced erratic measures in public health and hesitancy in acting. As an aftermath, the pandemic (see the number of deceased persons and infected survivors) erased the recent progress made in the field of global population health as well as both life and healthy life expectancy. The decline in life expectancy between 2019 and 2021 in most European countries (except for Luxembourg and Norway) ranged from marginal to unprecedented reduction (1.4-3.7 years!). Targets related to healthier populations and universal health coverage require substantial efforts to obtain the respective SDGs by 2030. (*OECD/EU, 2022, pp. 88-89, 107; WHO, 2022, pp. ix, 2, 14, 19, 48-53, 61, 82*)

Regarding the distribution in 2019 in the EU apart from COVID-19, cardiovascular diseases (most fatalities due to ischaemic heart diseases and cerebrovascular diseases) still rank number one on the list of major causes of death. Rolling back cannot be expected as most risk factors (high blood pressure and cholesterol level, low physical activity, obesity, and type 2 diabetes) are on the rise in many EU countries. Cancers (e.g. lung, colorectal, and breast cancer) occupy the second place followed by respiratory diseases, external causes of death (accidents, suicides, homicides, and other violent causes of

death), and Alzheimer's and other dementias. In 2019, 1.015 million premature deaths occurred in the EU, and 63.4% of them could have been prevented through primary prevention and public health interventions. The rest (36.6% of cases) was considered treatable through secondary health care interventions, including screening and treatment. *(OECD/EU, 2022, pp. 94-96, 144-145)*

The Human Development Index (as a composite indicator depicting progress made in the field of life expectancy, schooling, and economic performance) could grow without cessation from the beginning of the 1990s, but a rupture occurred after 2019 (outbreak of COVID-19) when its global value has fallen two consecutive years from 0.739 (value of 2019) to 0.735 in 2020, then, to 0.732 in 2021 by annihilating the achievements of the preceding five years. The official report of the United Nations Development Programme pointed out that a new uncertainty complex consisting of (i) planetary pressures and inequalities, (ii) societal transformations, and (iii) societal polarisation combined with global financial, climate, and food crises, as well as COVID-19 pandemic are curbing and reversing human development by affecting 9 out of 10 countries. Traumatising events, physical illness, general climate anxiety, food insecurity, and biodiversity loss are jeopardising mental well-being. Economic insecurity that manifests itself in financial shocks, unemployment, food insecurity, or low income may engender, exacerbate, and bequeath mental distress causing further considerable costs for societies. Mental distress can be attenuated through prevention, by mitigating crises and improving psychological resilience (for instance by deploying digitalisation with precautions, offering mental health services, and eradicating exclusion, disrespect, and discrimination). Worldwide, the two most frequent mental disorders were anxiety and depression affecting 300 and 280 million inhabitants respectively in 2019. 1 in every 8 people, amongst them more women than men, are suffering from mental disorders. Regarding age, 1 out of 5 children and adolescents and about 15% of adults aged 60 and over are living with a mental disorder. In spite of heritability, their treatable non-heritable factors are more relevant. (*UNDP, 2022, pp. 4, 12-13, 28, 74, 78-83, 90-95, 280*)

The uncertainties perceived in the previous years steered the attention to five key areas of health care:

1. In order to mitigate the vulnerability of health systems against future epidemics caused by infectious diseases and other shocks (e.g. corollaries of climate change,

armed conflict), crisis preparedness can be enhanced by building more sustainable and resilient health care systems and deepening partnerships. Reforms and targeted investments in prevention, health workforce, and health system digitisation enable nations to enlarge their response capacity (in the form of absorption, recovery, and adaptation).

2. Shifting towards earlier stages of the disease pathway in the case of cancer and other non-communicable diseases by means of better health promotion, disease prevention, and treatment results in improved disease management.
3. Exacerbation and proliferation of crises in tandem with those of a broad spectrum of mental health problems (including their risks) increase the demand for mental health care services.
4. New digital technologies (e.g. telemedicine replacing conventional alternatives thanks to commensurate accessibility) and dealing with data-related issues (e.g. collecting additional data on patients' experiences, enhancing both the quality and extent of digital solutions, ensuring greater availability of up-to-date health data, complying with data protection warranting citizens' control of own data, widening the geographical validity beyond the national level, and unleashing the potential of health data for multiple purposes like research, innovation, policymaking, and performance improvement of health care providers) accelerate progress towards the digital transformation of health systems.
5. Unifying resources in tackling effectively and efficiently health threats at a broader cross-border (e.g. international or global) level is of paramount importance.

In the course of 2020 and 2021, the downward spiral brought on by COVID-19 was twofold: (i) deteriorating general mental health and (ii) the insufficiency of mental health support due to disruption. This process was worsened by the confinements and less physical activity. The pandemic perturbed non-COVID care by causing postponed surgical interventions and longer waiting lists. The pandemic burdened the population disproportionately to the detriment of children and adolescents with regard to physical and mental health by leaving scars on their formative years as a consequence of the suspension of education and social activities plus aggravating behavioural risk factors (e.g. poorer physical health and unhealthy nutrition). As chronic illnesses, limitations in activities of daily living (e.g. functional disability), and mental disorders are widespread

in the circle of people aged 65 and over, the pandemic caused amongst others deficiencies in the provision of their long-term care. *(OECD/EU, 2022, pp. 3-5, 13-16, 23, 33-35, 87-89, 100, 104, 148, 197)*

A public health system can be considered as a multidimensional optimisation problem along numerous aspects, thereof five are briefly presented below. Practices are multifarious across the EU, and the health system of top-performing countries varies considerably, hence, one best way does not exist. *(OECD/EU, 2022, pp. 132-141, 177)*

1. How to finance health expenditure (compulsory contributory health insurance, government schemes, out-of-pocket payments, voluntary health insurance, other categories not listed earlier: charities, employers, foreign and undefined schemes),
2. how to assign health expenditure to functions (inpatient care defined as curative-rehabilitative care in inpatient and day care settings, outpatient care in ambulatory care settings or hospitals including home care and ancillary services, long-term care restricted to its health aspects, medical goods consisting of retail pharmaceuticals and therapeutic appliances, and collective services incorporating prevention and public health services, health administration),
3. how to prioritise primary health care services (prevention, dental care, general outpatient care, home-based curative care) in terms of health expenditure,
4. desirable level (absolute value per capita) of pharmaceutical expenditure, and
5. how to finance pharmaceutical expenditure (see the enumeration under 1).

My personal opinion rests on an unorthodox approach when claiming that in the plethora of current practices worldwide, setting enhanced capabilities (e.g. healthy life expectancy for both sexes at all ages) as principal performance indicators could function as a compass when evaluating the health system because simultaneous automatic accrual in basic capabilities can be assumed. An emphasised focus on preserving or restoring health instead of simply treating illnesses can ensure making the most out of unaltered budgets: maximising people's health and minimising the burden of diseases (health impairment, years of life lost, premature deaths, as well as concomitant social and economic losses).

The first group of the recommended actions exercises their impacts at the level of individuals through elevated health consciousness and strengthening the self-healing processes of the body (the listed elements are not disjoint):

- diminishing risk factors (e.g. through health education, incentives, campaigns raising awareness, limitations, bans coupled with products and eliminating the causes of environmental load),
- enhancing individuals' responsibility and active participation in preserving their health (e.g. preventive examination) and fostering their recovery (e.g. therapy),
- taking over further best practices applied outside the health system (e.g. popularising substances bearing the chance of prolonging life),
- involving areas demonstrating beneficial repercussions (e.g. mitigating education disparities, making more use of complementary medicine).

Second, measures related to health systems incorporate inter alia:

- alleviating overloaded health care systems (i) through building more capacities in the problematic fields (e.g. shortening waiting lists, long-term care for the elderly) and (ii) by decreasing the number of contacts with the health system (physical or online visits, treatments) to the justified minimum,
- in addition to the previous reduction, reviewing the composition by applying the hierarchy of interventions gradually (primary prevention and 1st level treatment, then, 2nd level health care interventions, including secondary prevention and treatment),
- striving to obtain efficient medical consumption and better intervention quality,
- deploying the untapped opportunities of digitalisation (e.g. new digital tools and more profound analysis of health data).

In the spirit of the concept outlined above, the first article launches a new easily interpretable metric apt for the mitigation of health risks by motivating individuals. As the outlook related to behavioural risk factors is alarming inter alia in Hungary, such a tool may enable similar countries lagging behind to catch up with better performers. The second article partially deals with environmental protection. Its subfield, the elimination of air pollution would be salutary for both human and environmental health. Although health issues are not amongst the priority areas of the third, fourth, and fifth articles, a more elevated level of environmental awareness in the circle of retail customers may create spillovers for or establish relationships with akin domains like health consciousness (e.g. *Castellini et al., 2023*) or financial intelligence (e.g. *HNB, 2022*).

2.8. State of health-conscious behaviour in Hungary in an international context

Many of the aspects of health-conscious behaviour are part of the regular data collection activity of statistical offices. The next sequence of tables (Tables 14-19)[14] extracts the main phenomena related to life expectancy and major behavioural risk factors prevailing in Hungarian society accompanied by comparative international data in the case of selected factors.

14. Table: Distribution of self-perceived health by sex and age group in 2022 in Hungary (*HCSO, 2023f*)

Sex/Age group	Very good or good	Fair	Bad or very bad
Females	60.76%	28.46%	10.79%
Males	65.80%	25.18%	9.02%
16–24	94.42%	4.47%	1.11%
25–34	90.32%	8.68%	1.00%
35–44	83.62%	12.91%	3.47%
45–54	69.52%	24.75%	5.73%
55–64	50.74%	35.94%	13.32%
65–74	29.05%	51.62%	19.33%
75 or more	15.34%	51.86%	32.80%

As outlined in Table 14, women reported better self-perceived health status. Its best valuation is monotonously decreasing with ageing. Table 15 elucidates that women consume less alcohol and the share of abstinent persons is the highest amongst the elderly. (*HCSO, 2021a*)

15. Table: Distribution of alcohol consumption patterns[15] by sex and age group in 2019 in Hungary
(*HCSO, 2021a*)

Sex/Age group	Heavy drinker	Moderate drinker	Occasional drinker	Abstinent
Females	1.5%	10.6%	49.3%	38.5%
Males	9.3%	30.9%	41.2%	18.6%
15–17	–	1.8%	44.3%	53.9%
18–34	5.9%	20.2%	52.7%	21.2%
35–64	5.7%	21.0%	47.7%	25.5%
65 or more	4.1%	21.3%	33.6%	41.0%

[14] The indicated percentages are correct. Alterations from a total of 100% are due to rounding.

[15] Heavy drinkers are those women who consume weekly more than 7 units of alcohol (on a daily basis: 5 dl of beer or 2 dl of wine or 0.5 dl of short drink or equivalent combinations), those men whose weekly consumption exceeds 14 units of alcohol (on a daily basis: 10 dl of beer or 4 dl of wine or 1 dl of short drink or equivalent combinations), and those affected by binge drinking, i.e. consuming 6 or more units of alcohol at one time. Moderate drinkers consume alcohol at least once a week but did not meet the criterion of heavy drinkers. The rest can be qualified as occasional drinkers. (*HCSO, 2021a*)

The first influencing factor to be investigated is nutrition. In Hungary, the older individuals are, the closer they are to the adequate consumption of both fruit and vegetables. Amongst women, increasing educational level is accompanied by eating more fruits and vegetables, however, for men, the direction of the connection is ambivalent. For ensuring protein intake, milk and dairy products are the most frequent sources followed by processed meat products. The two most typical diets in the circle of the elderly are diabetic and low-salt diets due to the increasing prevalence of both diabetes and hypertension with ageing. Energy-poor diet can be considered rather independent of age. Vegetarian, dairy-free, gluten-free, lactose-free, and other diets are popular in the circle of people aged between 15 and 64 years. (*HCSO, 2024b*)

Table 16 steers noteworthy attention to three main phenomena. (i) Proportionally more men cope with overweight and obesity: the gender difference is 13.3 percentage points. (ii) Unfortunately, growing old entails a marked failure in preserving the more advantageous juvenile weight. (iii) By contrasting the Hungarian data with the respective Austrian and Japanese statistics, bold prejudicial differences can be identified in the case of categories beyond normal weight. (*HCSO, 2021b*; *NIHN, 2023; Statistics Austria, 2020a*)

16. Table: Distribution of the population based on body mass index (BMI)[16] by sex and age group in 2019
(*HCSO, 2021b*; *NIHN, 2023; Statistics Austria, 2020a*)

Country	Range of BMI→ Sex/Age group↓	Underweight	Normal weight	Overweight	Obese
		less than 18.5	[18.5, 25.0[	[25.0, 30.0[	at least 30.0
Hungary	Females (15–)	3.9%	44.2%	29.2%	22.7%
	Males (15–)	1.4%	33.4%	40.1%	25.1%
	15–17[17]	19.1%	65.1%	8.6%	7.2%
	18–34	3.5%	57.2%	26.3%	13.0%
	35–64	2.0%	34.5%	36.2%	27.3%
	65–	1.0%	26.6%	42.5%	29.9%
Austria	Females (15–)	3.8%	53.8%	27.4%	15.0%
	Males (15–)	1.5%	39.2%	41.4%	17.9%
Japan	Females (15–)[18]	11.7%	66.4%	21.9%	
	Males (15–)	4.4%	63.8%	31.8%	

[16] BMI=weight in kilograms/(height in meters)^2 [kg/m^2]
[17] A few achievements in public education are e.g. daily physical education and the ban on selling unhealthy food products in school snack bars.
[18] Pregnancy and lactation are excluded.

As illustrated in Table 17, the gender gap (daily and casual smokers) in tobacco use is 6.1 percentage points to the disadvantage of men. The age group between 18 and 34 years is the most affected by this harmful custom. Both Austria and Iceland made successful advancements in stopping smoking. Inter alia, effective quit smoking products reducing symptoms of nicotine withdrawal are available for getting rid of this destructive habit. (*HCSO, 2021c*; *Statistics Austria, 2020b*; *Statistics Iceland, 2021*)

17. Table: Distribution of current smoking habits by sex and age group in 2019
(*HCSO, 2021c*; *Statistics Austria, 2020b*; *Statistics Iceland, 2021*)

Country	Sex/Age group	Daily smoker	Casual smoker	Quit smoking	Never smoked
Hungary	Females (15–)	22.3%	2.0%	14.3%	61.5%
	Males (15–)	27.7%	2.7%	22.1%	47.5%
	15–17	9.4%	5.7%	–	84.9%
	18–34	31.7%	5.1%	10.0%	53.2%
	35–64	28.7%	1.5%	18.8%	50.9%
	65–	12.0%	0.6%	26.9%	60.5%
Austria	Females (15–)	17.8%	4.7%	21.0%	56.5%
	Males (15–)	23.5%	6.6%	28.6%	41.3%
Iceland	Females (18–89)	8.4%	3.2%	35.5%	52.9%
	Males (18–89)	8.1%	2.8%	37.8%	51.3%

Table 18 shocks with its figures on how regular exposure to tobacco smoke causes inconveniences for non-smokers.[19] Furthermore, even the foetus is damaged in the case of pregnancy. Tobacco use is one of the death causes of trachea, bronchus, and lung cancer as well as ischemic heart diseases. (*HCSO, 2024c*)

18. Table: Distribution of non-smokers exposed to tobacco smoke by sex, place, and frequency in 2019 in Hungary
(*HCSO, 2024c*)

Sex	Place	Daily one hour or more	Daily less than one hour	At least once a week (but not every day)	Less than once a week
F	At home	31.2%	13.7%	18.5%	36.6%
M		20.9%	19.0%	13.9%	46.2%
F	Outside home	8.9%	10.4%	22.6%	58.1%
M		8.9%	11.1%	19.1%	61.0%

[19] The Act on the protection of non-smokers and certain rules for the consumption and distribution of tobacco products 1999, XLII envisages in its preamble to spare non-smokers (especially minors, pregnant women, patients, and handicapped persons) the exposure to tobacco smoke. (*NLD, 2024w*)

The World Health Organisation (WHO) recommends in its guidelines (*WHO, 2020a, pp. 32-34*) regular physical activity for adults aged between 18 and 64 years by indicating the weekly minimum duration and intensity of aerobic physical activity as well as the frequency of muscle-strengthening activities for achieving substantial or, beyond it, additional health benefits. Carrying out physical activity mitigates the mortality risk due to any cause of death or cardiovascular diseases, the incidence of hypertension and further cardiovascular diseases, type 2 diabetes, and site-specific cancers such as colon or breast cancer. It can improve mental health, cognitive functions, and sleep outcomes and attenuate weight gain resulting in overweight or obesity. Nonetheless, potential harms and risks may arise when doing physical activity.

The survey related to the physical activities of the Hungarian population concluded five fundamental statements concerning the WHO recommendation. (*HCSO, 2024d*)

1. The ratio of those complying with the WHO recommendation above neither in terms of the nature of work nor leisure time activities was 38.4% for women and 31.3% for men.

2. Ageing entails being physically less active irrespective of gender. Initially (18–34 years), men are more active but they lose their activity earlier than women.

3. Living in a less urbanised area is coupled with less physical activity.

4. In general, both the educational level and the improvement of the income situation increase the proportion of those who do muscle-strengthening exercises. The impact of the former factor on activity is bigger in most cases.

5. Shifting towards doing exercises in the optimal composition according to the WHO recommendation improves self-perceived health.

Partly thanks to the mitigation of the previous behavioural risks, women can reap the benefits in the form of both more favourable life expectancy and healthy life expectancy during their lifetimes. The relatively low Hungarian values in a Western international context, the differences between the indicators, and the gender gap suggest striving to exploit the room for improvement to the full as contrasted by means of Table 19. (*WHO, 2020b*)

19. Table: Life expectancy and healthy life expectancy in 2019[20]
(*WHO, 2020b*)

Country	Sex	Life expectancy		Healthy life expectancy	
		At birth	At the age of 60	At birth	At the age of 60
Hungary	Females	79.6 years	22.3 years	69.3 years	16.8 years
	Males	73.1 years	17.7 years	65.0 years	13.4 years
Austria	Females	83.8 years	25.6 years	71.9 years	19.4 years
	Males	79.4 years	22.4 years	69.9 years	17.2 years
Japan	Females	86.9 years	28.6 years	75.5 years	21.8 years
	Males	81.5 years	23.9 years	72.6 years	18.8 years

My stand on the improvement of the general health status of the population is that it predominantly rests on the individuals or the thoughtlessness of other individuals (e.g. transmitting detrimental patterns). Hence, the first article elaborates a risk assessment tool appropriate for heightening health consciousness in the circle of people aged between 40 and 65 years menaced by behavioural risk factors with the option of generalisability to both further age groups and countries beyond Hungary, the Czech Republic (countries at high cardiovascular risk), and Austria (low cardiovascular risk).

2.9. Alternative economic theories contributing to SDGs and redefining growth

Alternative economic theories are intermediaries of concepts endeavouring to realise more aggregated benefits from the interconnections amongst the three subsystems. Humanisation, embedding organisations into nature, and preserving the environment as guiding principles of these economic theories may allow us to create an economy in which organisations serve humans and advocate preserving, restoring or even widening ecosystems. The elimination of air pollution and its subset, i.e. decarbonisation are intertwined with Corporate Social Responsibility (CSR), the environmental dimension of Catholic Social Teaching (CST), and Ecological Economics. Even if climate change is a global process with locally different outcomes, all actors should keep in mind the possible global consequences of their actions exacerbating the atmospheric carbon dioxide or GHG concentration. (*Zsolnai, 1989, pp. 56-58, 113-117*) Creating Shared Value (CSV) complements the previous triad due to its spread.

[20] The last data prior to COVID-19 are more authentic. Slight differences can be identified compared to the content of Table 3 in subchapter 4.4.

In addition to the economic and legal components, the ethical and philanthropic responsibilities in the context of CSR appeal to enterprises to avoid harm and to improve the quality of life by allocating resources to communities. For example, these tenets may spur consumer behaviour changes through green marketing, research and development of low carbon technologies accompanied by their implementation in the production, and making use of carbon offsets for compensating emissions. (*Carroll, 1991, pp. 40, 42*)

CSV does not share the philanthropic aspect of CSR but complies with the view 'don't give a man fish rather teach him how to fish by himself'. Correspondingly, joint company and community value creation occurs simultaneously for both society and the economy. The basics consist of (i) improving lives, (ii) identifying new markets in serving unmet needs of underserved customer groups (e.g. low-income populations), (iii) making use of redesigned products, services or different distribution methods/channels, and (iv) promoting innovation and economic growth. (*Porter, 2011, pp. 6, 10, 13, 19, 20*)

The Christian-Jewish traditions offer propitious opportunities for improving societal awareness by sowing climate concerns. CST addresses ecological issues and considers climate as a common good: it summons mankind to a new and universal intra- and intergenerational solidarity. CST initiates to surmount the self-interested consumerism of affluent societies – by recognising that consumption is solely one of the means on the path to finding the true meaning of Existence – in order to master the current complex, not only environmental but also social crisis. It impels to spread system-level thinking under the umbrella of sustainability and ecological ethics through the medium of environmental education, furthermore, to take responsibility for and demonstrate commitment to the Earth and all creatures imbued with love and care. (*Pope Francis, 2015, pp. 13, 18-22, 103-104, 117-120, 153-157, 175*)

Likewise, Ecological Economics propound new ethical foundations that are grounded in reciprocity and the respect of all forms of Life and are characterised by the endeavour to create balance. Rupture with the hegemony of economy enables mankind to reposition the three subsystems and to shift towards a desirable world represented by the interlinkages of economy-in-society-in-nature. Following this approach, it is achievable to provide full employment and a high quality of life for everyone within the resource limits and ecological thresholds of Earth. This is a chance for reconfiguring production processes, redesigning goods and services, improving corporate values, rethinking the

notion of growth, and identifying areas for growth in such a way that the potential of human resources can be released and environmental health can be restored simultaneously. This fundamental transformation interlaces amongst others environmental justice, ecological politics, and social concerns. (*Brown–Timmerman, 2015, pp. 9-10, 241*)

By redefining the embeddedness of both the economy and society into nature, the SDGs offer a comprehensive framework, which performs in its entirety an instrumental role in achieving specifically the 13th SDG occupying a superior status. Combatting climate change necessitates the accomplishment of most SDGs.

All articles point to areas needing improvement and make suggestions for applicable tools but none of the articles deals with the emotional aspects of raising awareness or those of obtaining the inclination for self-restraint or voting in favour of future generations when facing the trade-off between outdated unsustainable practices and globally viable alternatives often coupled with extra efforts. My personal view on how awareness campaigns can be designed is represented by the possible variant that actions can be organised around a comprehensive risk-based approach. It relies on the understanding of system dynamics followed by risk awareness, then, by risk aversion, and applies in parallel emotional argumentation (e.g. responsible stewardship that manifests itself in intergenerational and international equity rooting in alternative economic theories). This ensemble of building blocks might induce the required series of climate responses – or air quality measures beyond them – in depth and breadth. Campaigns can be pursued in the circle of both individuals and companies. However, it was not involved in the scope of the articles on how to organise campaigns.

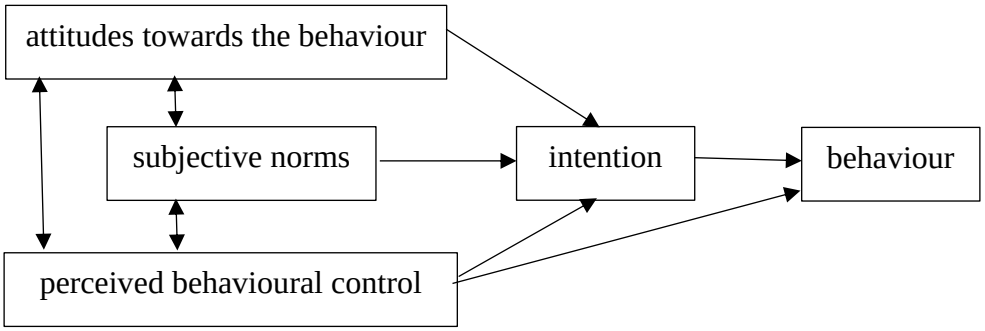
2.10. Environmentally conscious consumer behaviour

Numerous studies deal with the influencing factors of environmentally conscious consumer behaviour, one of the main structural axes of this dissertation. With the restricted aim of providing insight, a bunch of approaches (e.g. theory of planned behaviour, innovation diffusion theory, technology acceptance model) are presented here

by illustrating or describing their nomological networks[21]. Health consciousness as a related topic to the first article received meagre attention in this subchapter.

Various theoretical frameworks attempt to predict and explain human behaviour. One of them is the theory of planned behaviour. (*Ajzen, 1991, pp. 179, 181-182, 188*) Due to its central role in psychological processes, intention captures, on the one hand, motivational factors (e.g. attitudes representing individuals' evaluations, subjective norms referring to the impact of the reference group) influencing a given behaviour, on the other hand, non-motivational factors (e.g. perceived behavioural control or ability interpreted as the required opportunities and resources to perform the behaviour). Additionally, intention triggers the behaviour. Figure 5 is a simplified structural diagram without any feedback effects of behaviour on the antecedent variables. A few studies targeted at article-relevant topics such as environmentally conscious consumer behaviour, purchase intention, environmental consciousness, environmental commitment, and health consciousness are briefly disclosed in this subchapter.

5. Figure: Theory of planned behaviour
(*Ajzen, 1991, p. 182*)



A) Environmentally conscious consumer behaviour:

Pro-environmental attitudes incorporate amongst others (i) nature rules in the meaning of not transgressing the limits of nature and striving to preserve its delicate balance and (ii) humans rule interpreted in such a way that humanity rules over nature with having the capability of correcting any human-originated negative impact on the environment. In this context, the affinity for new ideas (the subset of consumer innovativeness) is a strong mediator of the link between pro-environmental attitudes and behaviours based on a survey made in the United States. This suggests that creating and

[21] A nomological network is a set of interrelationships between hypothetical constructs.

shaping the **propensity for accepting innovative ideas** increase the likelihood of acting green. (*Englis–Phillips, 2013, pp. 160, 164, 169-170*)

Two alternatives leading to environmentally conscious consumer behaviour, which have arisen from a research conducted in Central Europe, are outlined in the study of *Zabkar–Hosta* (2013, pp. 258-259, 261). First, **aggravating concern for the environment** enhances the willingness to behave in an environmentally conscious way. Subsequently, greater willingness induces environmentally conscious consumer behaviour, to which relationship increasing **pro-social** (antonym of being pro-self) **status perceptions** can give a stimulating impulse as moderator. Second, **being informed about environmental impact** entails environmentally conscious consumer behaviour as well.

Within the framework of the theory of planned behaviour, significant positive direct relationships could be identified between environmentally conscious consumer behaviour and its predictors such as **environmental concern**, **perceived consumer effectiveness**, and **willingness to be environmentally friendly** in Tunisia. In these connections, cultural dimensions can positively strengthen the relationships. In line with environmental consciousness, **collectivism** (opposite to individualism) and **long-term orientation** (instead of short-term orientation) can play a moderating role. (*Ghali-Zinoubi, 2022, pp. 6, 10-11*)

Exploring the nexus between environmentally conscious consumer behaviour and its predictors (e.g. **personal environmental norms**, **climate change beliefs**, and **environmental identity**) in Australia disclosed positive direct and mediated relationships. (*Perera et al., 2022, pp. 5, 10*)

The scope of environmentally conscious consumer behaviour can be restricted to subareas. One of them is the **willingness to pay a price premium** for energy-saving household appliances. *Zhang et al.* (2020, pp. 3, 6, 8, 10-11) carried out their scrutiny based on the theory of planned behaviour and consumer perceived value in China by applying the causal chain of influencing factors: attitude towards purchasing energy-saving household appliances, then, willingness to pay a price premium for them. Table 20 inventories the factors along major categories, indicates measurement items for interpretational purposes and their effect on the purchasing attitude. The relationship between purchasing attitude and willingness to pay a price premium is significantly positive. In addition to the purchasing attitude, both subjective norm and perceived

individual behavioural control of purchasing energy-saving appliances are positively related to willingness to pay a price premium, whereas age negatively impacts it. Gender, both income and educational level, and housing condition proved to not demonstrate significant interaction with willingness in this specific context.

20. Table: Influencing factors and their effect on the purchasing attitude (*Zhang et al., 2020, p. 10*)

Grouping category	Influencing factor	Effect on the purchasing attitude	
		Significant positive	Not significant
Perceived value related to the product	Quality value (e.g. advanced technology)	x	
	Price value (e.g. being economical in the long run)	x	
	Emotional value (e.g. evoking good feelings during use)	x	
	Social value (e.g. acceptance by others)		x
	Environmental value (e.g. environmental friendliness)	x	
Consumer	Environmental awareness (e.g. concerns about environmental problems)		x
	Personal norm (e.g. moral obligation to save scarce resources)	x	
Regulation	Perceived effectiveness of energy efficiency labelling institutional mechanism (e.g. avoiding energy efficiency label fraud)	x	
Publicity	Media publicity (e.g. advertisements on energy-saving appliances)		x

More sophisticated models can be established by involving **personality profiles**. The study of *Wang et al.* (2023, pp. 4, 8, 10) pointed to the necessity of a tailored, person-centred approach in order to link personality profiles with environmentally conscious consumer behaviour as identical psychological drivers may result in significant behavioural dissimilarities amongst consumer clusters in China.

Horváth et al. (2021, pp. 213-214, 222-228) collected – partly based on an international literature review – the main factors influencing household solar panel installations (it can be considered as behaviour) in both positive and negative directions with a focus on Hungary. These are:

- economic rationality (income, cost, government subsidies, financial indicators);
- socio-demographic factors (income level, educational level, number of children, age);
- housing circumstances (house or flat, own or rented dwelling, urbanisation);
- behavioural or attitude factors (e.g. environmental awareness, impacts of peers, imitation effects generated by users of innovation, prestige, consumer innovativeness, striving to autarchy);
- infrastructural conditions, and
- spatial location.

In addition, they identified a so-called small settlement effect in the sense that the diffusion can be traced back to a local innovator or solar market player.

B) Intention related to environmentally conscious consumer behaviour:

In the field of energy savings in China, *Xie et al.* (2021, pp. 4-6, 8) explored a sequence of linkages between **organisational intervention** and behavioural intention by inserting three psychological factors (attitudes, subjective norms, and perceived behavioural control) as in-betweens and relying on the moderating effects of two non-psychological factors (educational level and field-specific knowledge). They found significant positive relations in each pair of organisational intervention and psychological factor and of psychological factor and behavioural intention. Regarding significant moderating effects, energy-saving knowledge impacts positively the relationship between organisational intervention and both attitudes and perceived behavioural control. Similarly, educational level positively moderated the effect of organisational intervention on the three psychological factors.

In the field of generating intention to purchase electric vehicles in China, *Xie et al.* (2022, pp. 4, 8, 16-18) investigated the conceptual framework composed of the consecutive constructs of **innovation characteristics** (relative advantages, technology compatibility, and technological complexity), **risk perception**, and purchase intention. The mediator of **consumer lifestyle** on innovation diffusion (consciousness related to the triad of fashion, environment, and price) was added to the relationship between innovation characteristics and risk perception. Due to significant relationships, psychological activation techniques are appropriate tools for fostering purchase.

By targeting the diffusion of battery electric vehicles in China, *Wang et al.* (2021, pp. 2-4, 6) concluded that attitudes are the most important predictor of purchase intentions. Both perceptions of **incentive policies** (e.g. financial) and **consumer social attributes** (e.g. environmental concerns) are positively related to attitudes and purchase intentions, furthermore, **gender** demonstrated moderating effects.

C) Environmental consciousness:

In Australia, **external influences** (e.g. induced by retailers and peers) can more impactfully ameliorate the environmental consciousness of consumers in their consumption than internal factors such as self-image or being concerned for the environment. **Retailers** can play a more significant role in shaping environmentally conscious consumer behaviour than peers, thus, environmentally sustainable business practices are appropriate tools for raising awareness. (*Tsarenko et al., 2013, pp. 307-308*)

Jiménez Sanchez–Lafuente (2010, pp. 738-739) captured the grouping dimensions of predictors of environmental consciousness by **general beliefs/values**, **personal attitudes**, and **information/knowledge** in Andalusia (Spain).

D) Environmental commitment:

A survey performed in Malaysia elucidated that both environmental awareness of IT professionals and leadership commitment to workplace green IT practices positively influence engagement in green IT practices and environmental IT performance. (*Ojo–Fauzi, 2020, pp. 301, 304*) In China, environmental regulations, both environmental awareness and commitment of top managers can significantly and positively affect the eco-innovation performance of enterprises. (*Zhao et al., 2023, pp. 13, 16, 18-21*)

By scrutinising the Vietnamese hotel industry, green training, green rewards[22], and green organisational culture proved to be stimulants of employees' commitment to the environment. (*Pham et al., 2019, pp. 451-452, 460*) In the same sector in Malaysia, *Kuar et al.* (2022, pp. 160, 167, 174) pointed out that green practices can be traced back to their determinants manifesting themselves in (i) subjective norms, (ii) environmental knowledge, (iii) perceived benefits of green practices, and (iv) environmental commitment of top managers. As a part of the analysis, they investigated the nexus between (iv) environmental commitment and the first three factors by revealing significant positive relationships.

[22] E.g. free bicycles and electric cars provided by companies can be considered as green rewarding tools.

E) Linkages between health consciousness and other constructs:

In Italy, *Castellini et al.* (2023, pp. 3-4, 7) evinced a significant positive correlation between health consciousness and each of energy saving, recycling, and sustainable food consumption. Other dimensions of **pro-environmental behaviour** such as green purchasing and sustainable mobility demonstrated no significant association with health consciousness. By evaluating the questions concerning health consciousness, the sample showed fewer dissimilarities compared to environmental awareness. Sustainable mobility is the least popular practice, furthermore, the distribution of its scores is the most heterogeneous based on the relative standard deviation. Without testing how to increase health and environmental awareness, the authors anticipate favourable repercussions between them.

Rahamat et al. (2022, pp. 3, 5) elucidated that attitudes, subjective norms, and health consciousness positively influence intentions to use menu labelling, while the latter negatively impacts **purchase behaviour** in food service establishments in the USA.

F) Intention related to health:

In Japan, *Cao et al.* (2022, pp. 7, 9-10, 13) conducted a research aiming at revealing the influencing factors of behavioural intentions to use mobile health services in the circle of young Japanese adults aged at most 30 years. They found that **trust** in mobile health services, **performance expectancy** (i.e. usefulness of mobile health services in improving health), and **effort expectancy** (easy to use) influenced the behavioural intention through a positive direct linkage in each case. Regarding antecedents, two constructs – health consciousness and social influence – positively impact both trust and performance expectancy, while facilitating condition effort positively relates to expectancy. Perceived risk in connection with the personal information of users does not interact significantly with behavioural intentions.

The first article provides a new, more understandable metric assumed to be apt for enhancing health consciousness without testing it. Each further study lists influencing factors and/or the characteristics demonstrated by the actors in a more advanced situation. The findings can be translated into suggestions on how to promote digitalisation or environmentally conscious consumer behaviour (e.g. shaping policies). The presence of multicollinearity is investigated in the affected articles. Tables 26 and 27 in the Appendix provides more details.

3. Research design and summary of the main findings

3.1. Research goals

The quest of this doctoral dissertation is to heighten the consciousness of actors (individuals and SMEs) by suggesting effective and efficient tools or identifying room for improvement so that they commit themselves to SDGs or go beyond them. The first article is an attempt to raise awareness by virtue of an easily understandable metric to diminish cardiovascular risks, being the origin of the major causes of death. After offering an alternative on how to model cardiovascular risks (RQ1), the calculation of life expectancies based on the 10-year probabilities of fatal cardiovascular diseases (RQ2) enables the determination of gender- and age-specific gain in life expectancy between the two extreme cases by minimising cardiovascular risks (RQ3). Beyond RQ3, the generalisation of calculating gain in life expectancy applied to any situation by making use of life expectancies from RQ2 is obvious. The second article aims to identify the differentiating factors resulting in the rise from the less to the more competitive company group in the case of SMEs. It begins with compiling two illustrative maps that compare the industries and manufacturing branches of the Hungarian economy based on their air pollutant emission intensities (RQ1). As a second step, the selection of measures takes place so that the principal components of digitalisation and environmental protection can be created (RQ2). Finally, those single attributes (RQ3a) and principal components (RQ3b) are disclosed which proved to be differentiators concerning competitiveness. The third article investigates retail customers in selected fields of environmentally conscious behaviour encompassing home, mobility, heating and cooling, and governance. The dataset relies on the countries Hungary, Spain, and Ukraine. First, the most environmentally aware customers and their less conscious counterparts are characterised, accompanied by the question of whether the most environmentally aware customers outdo the others in each field (RQ1). Second, socio-economic phenomena are inventoried, which prevail in Hungary regarding environmentally conscious consumer behaviour (RQ2). The fourth article scrutinises consumer behaviour related to PV systems based on a database comprising five countries: Italy, Norway, Serbia, Ukraine, and the United Kingdom. Three RQs were formulated. First, the study attempts to distinguish (i)

prosumers from traditional customers, (ii) traditional customers having PV plans in the near future from those without such intentions, and (iii) countries from each other concerning energy choices and attitudes (RQ1). Second, the analysis sheds light on the role of information channels and that of installation reasons in decisions about PV systems (RQ2). Third, a closer look is taken at the nexus amongst the triad of having future PV plans, the routines for own energy conservation actions, and the evaluation of factors detaining other people from saving electricity (RQ3). Finally, the fifth article inspects consumer behaviour in the domain of residential routine mobility based on the experiences gained in Hungary, Italy, Norway, Poland, and Spain. The findings of the sole RQ intimate a bunch of recommendations to spur the choice for public transport, electromobility, mobility sharing business models, biking, walking, and further environmentally friendly alternatives.

3.2. Research model

The main central motives in terms of SDGs around which the articles turn are good health and well-being (3rd SDG) for the first study and climate action against climate change and its impacts (13th) for the remaining four articles. Not counting the 2nd article, whose addressees are corporate actors, the publications treat individuals as protagonists whose active participation is crucial in making noteworthy progress. The last three articles (3rd, 4th, and 5th) constitute an organic whole as they scrutinise the environmentally conscious consumer behaviour of retail customers by relying on the same dataset of the ENABLE.EU team.

Figure 6 is an abstract conceptualisation of the research carried out bearing the deficiencies of two-dimensional charts. It tries to place the particular articles in the comprehensive field of sustainable development in such a way that they form an organic whole through interlinkages. As specific subareas cannot be assigned to a sole SDG, ignoring SDGs enabled a more transparent indication of the fields of investigation.

6. Figure: Integration of the research fields of the articles
(The four RQs marked with italic font type are tightly interconnected.)

Health consciousness	1st article	**Target group**: individuals between 40 and 65 years **Year of data**: 2014–2019 **Aim**: mitigating cardiovascular risks **Findings**: creation of an easily understandable metric **Main benefits**: prolonging both life and health	RQ1: model of cardiovascular risks RQ2: calculating life expectancies RQ3: determining maximum gains
Corporate sustainability	2nd article	**Target group**: SMEs **Year of data**: 2018–2019 **Aim**: identifying best practices between company groups **Findings**: recommended measures of digital transformation and environmental protection **Main benefits**: enhancing corporate competitiveness	RQ1: map of industries and manufacturing branches RQ2: principal components of digitalisation and environmental protection RQ3: differentiating single attributes and principal components
Environmentally conscious consumer behaviour	3-5	**Target groups**: policymakers, individuals **Year of data**: 2016–2019	
	3rd article	**Aim**: clustering retail customers based on home, mobility, heating and cooling, and governance **Findings**: distinct dissimilarities between clusters **Main benefits**: profile-specific actions to elevate environmental awareness	*RQ1: levels of environmental awareness* *RQ2: social and economic characteristics*
	4th article	**Aim**: collecting motives of energy choices by mapping prosumers, customers with photovoltaic plans, and those without any plans **Findings**: distinguishing attributes of those planning or having photovoltaic installations **Main benefits**: tailored approach when promoting solar energy	*RQ1: differentiators related to photovoltaic installations and plans* RQ2: role of information channels and that of installation reasons RQ3: nexus between PV plans, energy conservation actions, and the evaluation of others' behaviour
	5th article	**Aim**: in-depth investigation of choices for environmentally friendly mobility **Findings**: potential enablers and disablers of environmentally friendly mobility **Main benefits**: improving the position of preferred travel modes	*RQ: influencing factors of preferred travel modes*

Each article proposes propitious opportunities to the benefit of all subsystems (society, economy, and environment). As the role of the individual is decisive in influencing his/her remaining life, the first article focuses on how to spur health consciousness by means of a simple risk assessment tool. It provides in an easily comprehensible way harvestable gains in life expectancy provided that the specific individual is inclined to mitigate health risk factors by renouncing tobacco use and modifying his/her less favourable habits affecting blood pressure and the level of total cholesterol. By selecting corporate actors as the target audience, the second study makes recommendations to less competitive SMEs on how to pare down their backwardness by deploying digital transformation and environmental protection. By returning to individuals, the third article attempts to classify

respondents from a general viewpoint into categories based on their level of environmental awareness and designate the areas to be improved so that a more elevated level can be achieved. The spread of clean technologies is indispensable for climate neutrality, thus, the subsequent, i.e. fourth analysis endeavours to identify prevailing patterns in the circle of prosumers of PV microinstallations, traditional customers with PV plans in the near future, and their counterparts without such intentions with the purpose of increasing the number of prosumers. The last member of the trio of articles that rely on the dataset of the ENABLE.EU team is the fifth research in the field of environmentally friendly mobility with the aim of determining factors that can promote the penetration of green(er) mobility. Table 21 indicates the published studies forming part of this article-based dissertation.

21. Table: Summary of the articles

No.	Title of the article	Journal and ranking	Year
1st	Providing new impetus to corporate well-being programmes: improving life expectancy through risk assessment	Hungarian Statistical Review, HAS A	2021
2nd	The outstanding role of digitalisation and environmental protection in enhancing corporate competitiveness	Hungarian Statistical Review, HAS A	2022
3rd	Analysis of retail customers in the field of environmentally conscious behaviour with respect to home, mobility, heating and cooling, and governance	Regional Statistics, SJR Q2	2023
4th	International comparative analysis of prosumers in selected fields of energy use and further customer preferences in environmental issues	Hungarian Statistical Review, HAS A	2023
5th	Common practices and dissimilarities in greening residential routine mobility in selected countries of Europe, based on a comparative analysis	Hungarian Statistical Review, HAS A	2023

Note: HAS A=domestic journal of A ranking in the list of the competent committee of Section IX of the Hungarian Academy of Sciences, SJR=Scimago Journal Rank

3.3. Data sources

By prioritising quantitative analyses, opting for specific topics related to fields of both immense extent and importance was driven by the combination of available data and the identified possible research gap. Three main sources can be indicated:

1. Statistical offices and further institutions (UNDP, WHO, World Bank, etc.) regularly provide (e.g. with yearly frequency) population health, morbidity, and mortality statistics, demographics, air pollutant emissions, and economic indicators. The time series enable the international comparison of the progress made.
2. The dataset of the CRC of the CUB contains data related to the competitiveness of SMEs (firms with more than 50 employees) in Hungary. The rate at which the survey with voluntary participation of SMEs is repeated is less often than the regular obligatory data supply to statistical offices. Until now, six phases took place: 1996, 1999, 2004, 2009, 2013, and 2018–2019. 234 enterprises operating in Hungary filled in the questionnaires of the last round, thereof 209 entities remained in the final sample. The typical industries are manufacturing (51%) and trade (24%), the rest are construction, transport and storage, accommodation and food service activities, and information and communication. Almost three quarters of the companies are held by domestic private owners. The database incorporates approximately 2,700, predominantly nominal and ordinal scale variables. It enables researchers e.g. to reveal the influencers of corporate competitiveness. The survey involved environmental protection merely in 2009, whereas digitalisation appeared in 2018 in the questionnaire. (*Chikán et al., 2019, pp. 4-5, 7; Chikán et al., 2010, pp. 32-34*)
3. As a result of an international household survey undertaken by the ENABLE.EU team between 2016 and 2019 in the circle of retail customers, the drivers of individual energy choices and behaviours were disclosed. In total 11,265 respondents from eleven countries filled in the questionnaire. The composition in alphabetical order: Bulgaria – 1,000 persons, France – 1,500, Germany – 711, Hungary – 1,022, Italy – 1,025, Norway – 1,221, Poland – 1,000, Serbia – 1,000, Spain – 760, Ukraine – 1,011, and the United Kingdom – 1,015. The survey comprises seven sections: (i) home/building characteristics and household

possessions, (ii) mobility, (iii) prosumers, (iv) heating and cooling, (v) electricity, (vi) governance, and (vii) social and economic characteristics. One of the deficiencies of the survey is that only a subset of country-section pairs is available for analysis. Similarly to the previous case, this dataset contains 473, overwhelmingly nominal and ordinal scale variables. (*ENABLE.EU team, 2019*)

3.4. Methods

My accumulated experiences underpin giving priority to quantitative research methods in each of the articles. While qualitative methodology can dive more profoundly into details on how research units perceive specific contexts and methods are adaptable for the investigated participants or cases, this methodology identifies only a subset of prevailing phenomena because of the low sample sizes, furthermore, they can neither bear the option of generalisability nor measure the prevalence of responses in the whole population. (*Kvale, 1994, p. 148*; *Ritchie et al., 2013, p. 4*) The arguments for opting for quantitative multivariate data analyses rest on the desire to reach farther, reveal stable and robust interrelationships, and gain patterns and distributions valid at the level of society and the economy by means of large samples ideally representative of the investigated population. These techniques were used for simplification as well as generating and testing hypotheses. (*Rencher–Christensen, 2012, p. 2*)

With regard to both the nature of the RQs and the depth and breadth of available data, uniformly quantitative methods were used. Nonetheless, the dataset of the CRC has a few limitations from the point of view of my research that could be subject to both exploratory qualitative and quantitative research. Correspondingly, future rounds of the CRC survey could be widened in order to investigate the propelling springs of both digitalisation and the commitment to the circular economy. Likewise, participating companies are not inquired currently about data disclosure related to GHG or carbon dioxide emissions and carbon footprint.

This subchapter provides a brief summary of the applied quantitative methodologies that are detailed in the underlying article. The main methods encompass ordinary least squares (OLS) linear regression and artificial neural networks (ANN) stand-alone or coupled with actuarial modelling of mortality by relying on gender-

specific mortality rates and smoking ratios. Both OLS linear regression and ANN are suitable for estimating the response variable based on predictors. Principal component analysis (PCA) was employed with the purpose of dimension reduction. Cluster analyses (both hierarchical and non-hierarchical, the latter also known as k-means cluster analysis) can create relatively homogeneous groups. Both logistic regression and probit analysis provide results between 0 and 1: logit models are suitable for binary response variables (thus the two discrete values), while probit models deal with continuous explained variables. Hypothesis testing was broadly used for normal distribution (Kolmogorov–Smirnov and Shapiro–Wilk tests), homogeneity of variances (Levene's test), and equality of means (depending on the fulfilment of the prerequisites: independent samples t-test or one-way ANOVA, asymptotic independent samples z-test). Deciding upon independence between two variables was carried out by dint of the chi-square test of independence and additionally, measures of association were calculated.

3.5. Summary of the main findings

The main objective of this dissertation is to identify a few areas to be improved with a special focus on the 3rd and 13th SDGs and to propose related means targeting individual or corporate actors so that their elevated level of consciousness can contribute to the achievement of SDGs. Table 22 sketches out the essence of the articles by indicating the geographical scope and their RQs along with both method(s) (M) and findings (F) in chronological order of the publication.

22. Table: Summary of the research questions, related methods, and main findings

Article (year)	Scope	Description of the research questions, applied methods, and their answers
First (2021)	HU, CZ, AT	RQ1: How can cardiovascular risks be modelled? M1: ANN enables the modelling of 10-year cardiovascular mortality rates. F1: These rates can be estimated based on gender, age, smoker status, systolic blood pressure, and total cholesterol. In the case of countries at high cardiovascular risk, the model rests on one hidden layer composed of four neurons with the hyperbolic tangent activation function for the hidden layer and with the identity activation function for the output layer. The most appropriate model of low cardiovascular risk can be characterised by two hidden layers: the first one consists of four neurons and the second one of three neurons. The hyperbolic tangent activation function proved to be the most adequate for the hidden layers and the identity activation function was applied for the output layer. RQ2: What are the life expectancies calculated based on the 10-year probabilities of fatal cardiovascular diseases as alternative metrics? M2: Conventional actuarial modelling was applied for estimating country- and individual-specific (depending on gender, age, smoker status, systolic blood pressure, and total cholesterol) mortality rates due to any cause of death. The calculations were based on (i) 10-year mortality rates of fatal cardiovascular diseases, generated by the functions provided by the multilayer perceptron separately for countries at high cardiovascular risk and low cardiovascular risk, (ii) country-specific population mortality rates split by gender and age, (iii) country-specific smoking ratios split by gender, (iv) country-specific death statistics due to cardiovascular diseases split by gender and age group, (v) the population (i.e. the whole society) of the underlying country split by gender and age. Due to the lack of more detailed data, simplifying assumptions were made: smoking ratios were applied uniformly irrespective of age as well as symmetric distributions were presumed regarding systolic blood pressure and total cholesterol. In order to reproduce fact death cases, an adjustment of these probabilities with multipliers was required. F2: Free-to-download tables (A1-A3) (see http://www.ksh.hu/statszemle_archive/en/2021/2021_01/2021_01_017_annex.xlsx) align the life expectancies for each health status in HU, CZ, and AT. RQ3: What is the estimated maximum gender- and age-specific gain in life expectancy between the two extreme cases by minimising cardiovascular risks? M3: The differences can be determined by relying on the free-to-download tables.

<table>
<tr><td></td><td></td><td>F3: The gains in life expectancy for individuals aged 40 years:
<table>
<tr><th>Years</th><th>HU</th><th>CZ</th><th>AT</th></tr>
<tr><td>Females</td><td>(43.4–36.2=) 7.2</td><td>(45.8–37.8=) 8.0</td><td>(46.6–41.3=) 5.3</td></tr>
<tr><td>Males</td><td>(37.4–28.0=) 9.4</td><td>(39.7–29.7=) 10.0</td><td>(42.3–35.7=) 6.6</td></tr>
</table>
The gains in life expectancy for individuals aged 65 years:
<table>
<tr><th>Years</th><th>HU</th><th>CZ</th><th>AT</th></tr>
<tr><td>Females</td><td>(21.2–15.6=) 5.7</td><td>(23.0–16.6=) 6.4</td><td>(23.4–19.3=) 4.1</td></tr>
<tr><td>Males</td><td>(17.1–11.3=) 5.8</td><td>(18.2–12.3=) 5.9</td><td>(20.0–16.1=) 3.9</td></tr>
</table>
The statement regarding the order of countries (HU<CZ<AT) based on the life expectancy is valid not only for the selected ages but can be also generalised to each health status.</td></tr>
<tr><td>Second (2022)</td><td>only HU</td><td>RQ1: How can industries and manufacturing branches be characterised and ranked in relation to each other in terms of their air pollutant emission intensities through the example of the Hungarian economy?
M1: PCA was performed by applying two variants. The first one relies on 2 components and 7 molecules (dinitrogen oxide, nitrogen oxides, ammonia, non-methane volatile organic compounds, carbon dioxide, sulphur oxides, and carbon monoxide). The second one is a slight alteration: it ignores nitrogen oxides while keeping the 2-component structure.
F1: The critical industrial areas include:
(i) energy supply (largest intensities of CO_2 and SO_X plus noteworthy NO_X and CO emissions),
(ii) agriculture, forestry, and fishing (largest N_2O, NO_X, NH_3, and NMVOC intensity),
(iii) five emission-intensive manufacturing branches:
(a) wood and paper products and printing (less but still salient NMVOC and NO_X intensity),
(b) coke and refined petroleum products (CO_2, NO_X, and SO_X intensity),
(c) chemicals and chemical products (considerable intensities of CO_2, NO_X, SO_X, and NMVOC),
(d) rubber and plastic products and other non-metallic mineral products (CO_2, NO_X, and SO_X intensity),
(e) basic metals and fabricated metal products, except machinery and equipment (largest CO intensity, SO_X).

RQ2: Which set of measures is the most appropriate for dimension reduction by creating the principal components of digitalisation and environmental protection?
M2: PCA enabled dimension reduction in such a way that 52 variables were categorised into 11 components. Thereof 27 variables compressed into 6 components pertain to digitalisation, while the remaining 25 variables of 5 components represent environmental protection.</td></tr>
</table>

		F2: Digitalisation can be captured by six principal components: (i) preparedness for digitalisation, (ii) corporate level of digitalisation, (iii) digitalisation applied by leading enterprises of the industry, (iv) basic digitalisation tools, (v) advanced digitalisation tools, and (vi) technology use and change. Environmental protection can be divided into five subareas: (i) basic environmental management tools, (ii) advanced environmental management tools, (iii) environmental and social aspects of sustainability, (iv) sustainability performance compared to competitors, and (v) procurement. Tables 6 and 7 of the third article enumerate the 52 measures. RQ3: Which of the (a) single attributes and (b) principal components in digitalisation or environmental protection can be considered differentiating in terms of competitiveness? M3: (a) The employed tests target normal distribution (Kolmogorov–Smirnov test), the homogeneity of variances, and the equality of means (independent samples t-test or one-way ANOVA). (b) In addition to carrying out the Kolmogorov–Smirnov test, Levene's test for equality of variances, and independent samples t-test, Pearson correlation coefficient between the Technology Index built from the principal components and the standardised Competitiveness Index and that between the Environmental Protection Index built from the principal components and the standardised Competitiveness Index were calculated and tested. Running a series of non-hierarchical cluster analyses was useful in judging statements based on the final cluster centres. F3: (a) More competitive and typically small and medium-sized Hungarian companies are more intensely impacted by a shortage of qualified workforce that impedes their innovation activities compared to less competitive firms. (b) More competitive companies outperformed the less competitive ones in all investigated dimensions, not counting digitalisation applied by leading enterprises of the industry, instruments of advanced digitalisation, and basic environmental management. Deepening digitalisation or environmental protection (except for procurement) promotes the competitiveness of less competitive firms. Nonetheless, achieving better competitiveness does not necessitate a higher performance in any of the two fields within the more competitive group.
Third (2023)	HU, (ES, UA)	RQ1: Which characteristics describe the most environmentally aware customers and their less conscious counterparts by relying on the countries Hungary, Spain, and Ukraine and applying a commonly used standard for ensuring comparability? Do the most environmentally aware customers demonstrate excellence in each field? M1: Both hierarchical and non-hierarchical cluster analyses were employed in order to create relatively homogeneous customer groups based on their level of awareness. Then, asymptotic independent samples z-tests were performed to test the equality of group means.

		F1: As the most environmentally aware customers demonstrate a less conscious attitude in (1) the total travelled distance, (2) opting for environmentally friendly alternatives concerning both (a) mobility and (b) household appliances, and (3) accepting environmentally friendly measures that may cause inconvenience for them, the generalisability (i.e. excellence in each field: home, mobility, heating and cooling, governance) of environmental awareness can be declined in the circle of retail customers. The group, which occupies an environmentally friendly position in mobility, cannot be considered environmentally aware, as it underperforms in many scrutinised dimensions. RQ2: Which socio-economic phenomena prevail in Hungary regarding environmentally conscious consumer behaviour? M2: Again, the asymptotic independent samples z-test was apt to test the equality of group means. F2: The most environmentally aware customers build the most homogeneous group, as it is composed of the most educated, economically active urban citizens with family (living in a household with 2.7 members on average) and stable financial background. In the case of respondents lagging behind the best performers, a few favourable attitudes can be traced back to economic or demographic reasons, otherwise, they demonstrate significant deviations from the best performers.
Fourth (2023)	RQ1: IT, NO, RS, UA, UK RQ2: IT, NO, UA, UK RQ3: RS, UK	RQ1: Which variables qualify as differentiators when comparing (i) prosumers with traditional customers, (ii) those having PV plans in the near future with those without such intentions, and (iii) country groups/countries with each other? M1: Asymptotic independent samples z-tests were performed on the three mentioned levels to test the equality of means. Logistic regression was employed as an alternative quantitative method for binary classification for both cases (i) and (ii) but the models were useless for predicting both prosumers and traditional customers with PV plans in the near future. F1: In the contexts of (i) and (ii), the respective more conscious group is better educated and has a more stable financial background. Its members achieved a higher proportion of energy-efficient bulbs inside their homes, which are on average single-family houses attached to building(s). These dwellings are more likely to be equipped with smart meters. They consume less energy thanks to environmentally friendly alternatives and agree more strongly with the inconvenience arising from eco-friendly measures. In addition, in the context of (ii), traditional customers with PV plans have a larger family, demonstrate a higher share of men and more commitment to environmental issues, and are younger and economically more active than their counterparts without plans. In the context of (iii), this study identified phenomena with distinctive dissimilarities between Western and Eastern states in the aspect of size and current income of the household, use of energy-efficient bulbs and smart meters, less energy consumption due to mobility and household appliances, and accepting the inconvenience coupled with environmentally friendly measures. Furthermore, the comparison between Norway and Italy pointed to significant country specificities regarding (1) the weekly total travelled distance (longer distance: NO), (2) opting

		for environmentally friendly mobility (more inclined: IT), (3) supporting government actions affecting the transport system (more supportive: IT), and (4) estimating the severity of traffic problems (more tolerant: NO). RQ2: Which conclusions can be drawn with regard to the role of information channels and that of installation reasons when making decisions about PV systems? M2: It was made use repeatedly of asymptotic independent samples z-tests to test the equality of means. F2: Prosumers give priority to formal information channels (one-sided p-value: 6.01%) when acquiring information about PV systems. Both in the circle of prosumers and those with PV plans in the near future, technological reasons are the least motivating drivers of installation, followed by environmental and finally by other (e.g. financial) motives. RQ3: What kind of interrelationships can be identified amongst having future PV plans, the routines for own energy conservation actions, and the evaluation of factors detaining other people from saving electricity? M3: Cross-tabulation analyses or, by other name, chi-square tests of independence were carried out by relying on two ordinal variables in four contexts as detailed below. (i) The number of routines for own energy conservation actions influences the opinion about why others do not participate in saving electricity. This statement was tested at the country level. (ii) Customers with PV plans demonstrate a stronger negative association between the number of routines for own energy conservation actions and the score given to estimate the factors detaining others from saving electricity than their counterparts without such intentions. This assertion was tested on the merged sample. (iii) Customers with PV plans have more routines for own energy conservation actions than their counterparts without such intentions. Here again, testing was country-specific. (iv) Customers with PV plans are more able to evaluate the factors detaining other people from saving electricity with less score, thus, their opinion is closer to the reality. The analysis occurred split by country. The strength and sign (negative, zero, or positive) of the association between the two ordinal variables in each hypothesis were characterised by measures of association (both symmetric and directional ones if the latter type was reasonable) and their tests. Asymptotic independent samples z-tests were employed in the case of both hypotheses (iii) and (iv) with the purpose of validation. F3: (i) Serbia demonstrates a weak negative (one-sided p-value: 6%), whereas the United Kingdom demonstrates a stronger contradictory positive association between the number of routines for own energy conservation actions and the evaluation of factors detaining other people from saving electricity.

		(ii) These two variables proved to be independent when distinguishing traditional customers along PV plans in the near future on the merged dataset of the two states. (iii) and (iv) British individuals with PV plans in the near future have more routines for energy savings and overestimate others' passive attitudes more than citizens without such intentions. In Serbia, these dissimilarities are not significant.
Fifth (2023)	HU, IT, NO, PL, ES	RQ: Based on the experiences gained in Hungary, Italy, Norway, Poland, and Spain, and the timeshare of preferred travel modes (compounded variable), what are the main influencing factors of residential routine mobility choices promoting public transport, electromobility, mobility sharing business models, biking, walking, and further environmentally friendly mobility solutions? M: OLS linear regression, probit analysis, binary logistic regression, and ANN were used for revealing the predictors. Each model proved to be apt for enlarging the circle of factors. Asymptotic independent samples z-tests served for comparing means. F: Depending on the underlying model, the factors can be country-independent or country-specific. The results show alterations in both the initial and final sets of independent variables and the final sample sizes along models for the particular countries. The union of the <u>enablers</u> consists of (i) lower travel fares (decisions based on cost), (ii) occupying a more supportive stance on government actions affecting the transport system, (iii) being more satisfied with transport facilities, (iv) consuming less energy thanks to environmentally friendly alternatives, (v) being economically less active, (vi) female, and (vii) member of younger age groups, (viii) considering CO_2 emissions, (ix) dwelling in urban areas, (x) assessing positively infrastructure development, (xi) possessing four-wheel electric and (xii) two-wheel traditional vehicles, and (xiii) facing financial difficulties (as they shift people towards less air polluting modes). <u>Disablers</u> are (i) owning four-wheel traditional vehicles, (ii) less flexibility of preferred travel modes, and (iii) considering traffic problems more seriously. Additionally, the investigation brought a few paradoxes to light. <u>Conflicting effects</u> are demonstrated by (i) the safety, (ii) availability, and (iii) reputation of travel methods, (iv) travel time, and (v) occupying a supportive position regarding environmental issues. Without indicating the direction, ANN pointed to <u>further common factors</u>: (i) purchasing cars or motors from public means and (ii) making use of bike-sharing.

Note: AT=Austria, CZ=Czech Republic, ES=Spain, HU=Hungary, IT=Italy, NO=Norway, PL=Poland, RS=Serbia, UA=Ukraine, UK=United Kingdom

3.6. Validity and reliability

‘Validity is broadly defined as the state of being well grounded or justifiable, relevant, meaningful, logical, confirming to accepted principles or the quality of being sound, just, and well founded.’ Reliability ‘is the idea of replicability, repeatability, and stability of results or observation.’ (*Cypress, 2017, p. 256*)

The means listed below enabled me to treat validity threats and reliability issues and thus improve quality:

- checking the plausibility of results and preferring prudence in the case of life expectancies, and adjusting own calculations by applying multipliers so that they can be reconciled with the reality regarding death cases due to cardiovascular diseases,
- striving to apply large samples (see the section Data collection in each of the articles),
- excluding cases through the lens of reasonability (e.g. travel time was not plausible or more than 1 day, or calculated velocity was above 140 km/h),
- relying on more authentic data sources (see subchapter 3.3 and the section Data collection in each of the articles),
- opting for the last available relevant data,
- ensuring consistency of data (e.g. opting for the same or nearest year, eliminating contradictions or mistakes, treating uniformly missing values represented by the ‘Do not know’ or ‘Did not answer/No answer/Refuse to answer’ or ‘Not applicable’ records),
- minimising data loss when deciding about transformations (e.g. applied approach in the case of transformed variables used in the third, fourth, and fifth articles),
- employing alternative methods (e.g. logistic regression as a supplement to asymptotic independent samples z-tests),
- contrasting the findings with the postulates of other publications (see the sections Discussion),
- identifying paradoxes, ambivalent impacts, and model dissimilarities,
- pointing to country-specific phenomena restricting validity.

3.7. Limitations

The limitations hindered the disclosure of more meaningful or realistic results. They can be classified into three main categories as listed below.

1. Selection of variables:
   - neglection of relevant predictors (e.g. supplementary risk factors in the first article or further relevant air pollutants in the second study),
   - lack of revealing causal relationships or mediating effects between variables.
2. Data-related issues:
   - restrictions in the dataset (e.g. the dataset containing the probabilities for the occurrence of fatal cardiovascular events within 10 years was restricted to 40–65 years, not surveyed variables related to the circular economy, missing variable hinting at the national or international nature of routine mobility, ignored holiday travels, the low proportion of positive or affirmative answers),
   - making use of aggregation (e.g. statistical offices provide the number of deaths due to cardiovascular diseases only by age group),
   - introducing simplifying assumptions (e.g. applying identical smoking ratios irrespective of age or symmetric distributions regarding systolic blood pressure and total cholesterol),
   - lack of data caused by empty records (e.g. in the case of the ENABLE.EU team),
   - data inadequacy (e.g. only carbon dioxide emissions can be utilised as the carbon footprint is not published by industry and manufacturing branch),
   - not representative database (e.g. that of the CRC or the ENABLE.EU team),
   - partly outdated results due to the commencement of the survey (e.g. bold advancements could not be captured as the origin dates back to 2016).
3. Model limitations:
   - creating interactions between variables was not applied,
   - models consisting of first-degree variables (disregard of further model types e.g. quadratic).

The research results are published in single authored articles which are presented by following the conventional structure of scientific peer-reviewed articles: introduction, literature review, method, data collection, data analysis, findings, discussion, conclusion, limitations, and further research. Finally, a summary concludes the dissertation.

4. Providing new impetus to corporate well-being programmes: improving life expectancy through risk assessment

Hungarian Statistical Review. 2021. 4(1). pp. 17-50. 10.35618/hsr2021.01.en017

Abstract

Diseases of the circulatory system are leading causes of death, which compel stakeholders to lessen cardiovascular risks by utilising more effective prevention. These risks can be estimated based on gender, age, smoker status, systolic blood pressure, and total cholesterol. Artificial neural networks enable the modelling of 10-year cardiovascular mortality rates. Understandable communication of potential gains in life expectancy may enhance health consciousness by mitigating behavioural risks. The reproduction of death statistics requires the adjustment of the recommended probabilities for the occurrence of fatal cardiovascular events. This study deals with countries at high and low cardiovascular risk, selecting Hungary and the Czech Republic (high risk), and Austria (low risk).

In Hungary, the gains in life expectancy are (43.4–36.2=) 7.2 years[23] for females and (37.4–28.0=) 9.4 years for males, both aged 40. These figures moderate to (21.2–15.6=) 5.7[24] and (17.1–11.3=) 5.8 years for elderly people aged 65, respectively. The Czech Republic represents an interim phase between the two other countries regarding advancement in life expectancy, the respective gains exceed the Hungarian values: (45.8–37.8=) 8.0, (39.7–29.7=) 10.0, (23.0–16.6=) 6.4, and (18.2–12.3=) 5.9 years. In contrast, a 40-year-old woman may benefit from an additional (46.6–41.3=) 5.3 years in Austria, while the corresponding accrual for men is (42.3–35.7=) 6.6 years. On reaching 65 years, the increment is (23.4–19.3=) 4.1 and (20.0–16.1=) 3.9 years.

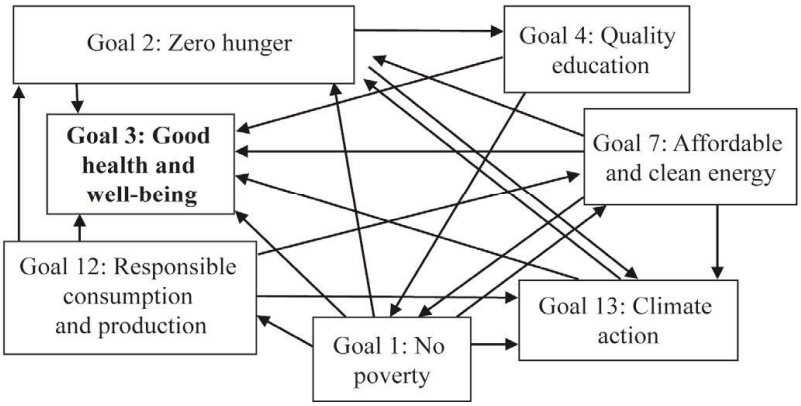
Keywords: life expectancy, well-being, cardiovascular risks

[23] The results are indicated as the difference in life expectancy between the best and worst observed health statuses.
[24] The indicated figures are correct, the difference in the decimal place is due to rounding.

4.1. Introduction

On the 25th of September 2015, the General Assembly of the United Nations adopted 17 Sustainable Development Goals (SDGs) to be achieved by 2030. The 3rd SDG ('Ensure healthy lives and promote well-being for all at all ages') occupies a higher level in the hierarchy of goals as its accomplishment requires fulfilling and harmonising other SDGs. Figure 1 illustrates the relatively difficult advancement in the 3rd SDG, which the present study aims at bolstering by virtue of its target of 'Strengthening the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks'. (*United Nations, 2015, pp. 1, 14, 17*)

Figure 1. Causal dependencies between selected SDGs (extract, own compilation)



Note: Each arrow starts from the prerequisite.

Life expectancy (the average number of years that a person can expect to live) and its subset, healthy life expectancy (the life expectancy reduced by the years lived in less than full health due to disease or injury) are indicators describing the current state of and the progress in well-being. Both can be calculated not only at birth but also for all ages. Using the data of the countries of the EU (European Union) plus Norway and Iceland, the gender-independent estimate for the continually growing maximum of the healthy life expectancy valid for 2016 was 76.7 years at birth. In the same year, Spain represented the highest unisex healthy life expectancy at birth in Europe with 73.8 years. Only Japan (74.8 years) and Singapore (76.2 years) ranked before the Mediterranean state, whereas Hungary lagged behind with 66.8 years. An additional 8.7 years – for this figure, see *Vona* (2020, pp. 99-100) – could be achieved through the reduction in preventable causes of mortality via effective primary prevention and public health care. The remainder (76.7–66.8–8.7=1.2 years) is lost owing to environmental factors. In the Czech Republic,

healthy life expectancy is 69.3 years and the two respective components amount to 6.3 and 1.1 years. Austria, the third member of the triad demonstrates 72.4, 3.8, and 0.5 years. (*UNDP, 2018, pp. 50, 53; Vona, 2020, pp. 99-100*) Another manifestation of the difference between the three countries can be captured in the life expectancy at birth: 72.9 years for Hungarian males and 79.3 years for females in 2019 compared to the estimated EU-27 average in 2019 of 78.5 and 84.0 years, respectively. Both the Czech and Austrian figures exceed the Hungarian ones. At the same time, achieving the Japanese indicators (in 2019, 81.5 years for men and 87.7 years for women) would make the retirement period extended for both sexes in Hungary by approximately one decade. (*HCSO, 2021a; EC, 2021; UNDP, 2020, p. 356*) The practice of Spain affirms that generally effective public health and health care interventions are appropriate but not sufficient in terms of addressing premature mortality as mortality rates offer abundant leeway for improvement in spite of the advantage of Spaniards compared to the EU citizens. Furthermore, it projects the growing need for health care and long-term care for elderly people in ageing societies. (*OECD–EOHSP, 2019c, pp. 3, 22*) This highlights the need to seek for new opportunities and employ additional measures to boost both life expectancy and its subindicators.

As evident solutions can be considered building more on prevention and health promotion, involving relevant stakeholders and providing them with health risk assessment tools, which can establish an early warning system. They could improve morbidity and preventable mortality plus alleviate overloaded health care systems. Regarding stakeholders, firms and non-governmental organisations can play a crucial role. In 2019, 856,950 active enterprises operated in Hungary (preliminary data) and the economically active population aged between 15 and 74 years exceeded 4.67 million persons. (*HCSO, 2021b; HCSO e-Shelf, 2021, Table 3.1.1*) Running extended corporate well-being programmes may reduce the expenditures on sick leave and sick pay (in 2019, they amounted [81+127=] 208 billion HUF, which in total accounted for 0.44% of GDP; the number of calendar days of sick leave and sick pay was [11.4+26.5=] 37.9 million days). (*HCSO e-Shelf, 2021, Tables 3.5.23-3.5.24, 4.1.8*) In addition, 2,791 health and 10,873 sport non-governmental organisations (the sum of the number of foundations and membership organisations) can be mobilised for spreading health consciousness (data valid for 2019). (*HCSO e-Shelf, 2021, Table 4.2.14*) In both the Czech Republic and Hungary, ischaemic heart disease, stroke, and cancer account for a significant share of deaths, while risk factors coupled with unhealthy behaviours (poor diet, smoking, alcohol

consumption, and low physical activity) are responsible for half of all deaths. (*OECD–EOHSP, 2019a, pp. 5, 7, 2019b, pp. 5, 7*) In contrast, this latter proportion is merely 39% in the EU.

This study focuses on circulatory system diseases as they are the leading cause of death (49.1% of all death cases in 2019 in Hungary and 42.2% in Czechia). Effective primary prevention performed by corporate well-being programmes may provide a remedy for this situation. (*HCSO, 2020a, Table 6.2.20; Czech Statistical Office, 2021a*)

This research is motivated by the idea that treating individuals as precious resources necessitates the recognition and spread of the value of prolonging health. Thus, the present study creates a basic risk assessment tool for cardiovascular risks that quantifies potential gains in life expectancy by shifting from a chosen initial health status towards more favourable targets. These risks are represented by a group of disorders including 'hypertension (high blood pressure), coronary heart disease (heart attack), cerebrovascular disease (stroke), peripheral vascular disease, heart failure, rheumatic heart disease, congenital heart disease, and cardiomyopathies'. (*WHO, 2021*) The results confirm that the proposed tool can provide easily understandable increments in life expectancy. Hence, the chance that individuals are committed to health consciousness increases by generating multiple direct and indirect benefits, which reflects the practical relevance of the research in addition to its theoretical contribution.

4.2. Literature review

To identify a possible research gap, the extensive field of health promotion programmes is presented in a simplified way by aligning the most frequent streams of research, following a chronological order. Consequently, the review incorporating studies from the last two decades clarifies and outlines the main themes and development in the research field. On the one hand, the selected areas encompass definitions and conceptualisations of health and well-being, identifying the impacts of health promotion programmes on performance indicators such as work-related outcomes with a special focus on financial results or customer loyalty, and quantifying these impacts (e.g. return of investment). On the other hand, cases analysing the relationship between health risk factors and an aggregate variable such as health-related costs or all-cause mortality, and refining the involved determinants when assessing risks to be managed within the framework of well-being programmes, have proved to be of interest. After a brief

overview of the Hungarian literature, this listing is complemented with the role of company attributes (e.g. firm size) in the intensity of corporate well-being programmes, making use of new approaches supported by technology (e.g. gamification), and the concomitant benefits of increased well-being.

Danna–Griffin's (1999, pp. 357, 359-360) study can be considered as a basic work providing definitions and conceptualisations of health and well-being via a literature review. The authors' applied framework is based on three pillars represented by antecedents, well-being in the workplace, and consequences. Antecedents are divided into three categories: work settings, personality traits, and occupational stress. Well-being (both life and job-related satisfaction) is targeted at providing mental and physical health in the workplace. The third pillar unifies individual (physical, psychological, and behavioural) and organisational consequences (health insurance costs, productivity affected by absenteeism, etc.) to be relieved through improved well-being and health.

Aldana (2001, pp. 296, 297, 299, 315, 317, 318) investigated the impact of health promotion programmes on financial outcomes with a primary focus on health care costs and employee productivity. Through an extended literature review of health intervention studies, the author revealed that stress, excessive body weight, and multiple risk factors are associated with increased health care costs and illness-related absenteeism. In contrast, lack of fitness (physical activity) implies only augmented health care costs but may not affect absence from work. Beyond mitigating many health risks, health promotion programmes result in lower levels of employee absenteeism and employee-related health care expenditures, while fitness programmes show only partial progress in the form of moderated health care costs.

Of the selected articles, two deal with workplace health promotion based on financial returns by applying the indicator of return on investment. *Baicker et al.* (2010, pp. 304-305, 308, 310) conducted a meta-analysis of the literature on costs and savings arising from employer-based wellness initiatives by putting decreased health care costs and lessened absenteeism at the forefront out of the numerous potential benefits (e.g. improved health, ameliorating productivity, lower replacement costs for absent employees, firm's attractiveness when recruiting workers). They concluded that workplace disease prevention and wellness programmes can lead to savings (avoiding absenteeism costs and a drop in medical costs) even in the short term; the underlying studies examined well-being programmes for 2-3 years on average. *Baxter et al.* (2014, pp. 347, 357) examined the relationship between return on investment and quality of

study methodology in workplace health promotion programmes through systematic literature search. Like *Baiker et al.*, they found a positive return on investment. Furthermore, they pointed to the phenomenon that studies of higher methodological quality demonstrated smaller financial returns.

Focusing on a frequently cited work (*Goetzel et al., 1998*)[25], *Goetzel et al.* (2012, pp. 2475, 2478, 2480-2482) examined ten modifiable common health risk factors (depression, blood glucose, blood pressure, body weight, tobacco use, physical inactivity, stress, cholesterol, nutrition and eating habits, alcohol consumption) to support through cost prediction evidence-based health promotion and risk-reduction programmes. Despite variations in the prevalence of risks, the authors determined similar relationships between risks and medical expenditures after more than one decade. They identified seven of the listed health risks (exceptions: cholesterol, alcohol consumption, nutrition and eating habits) worth mitigating for reducing related future costs.

Loef–Walach (2012, pp. 164-165, 169) selected five lifestyle factors (smoking, diet, physical activity, alcohol consumption, obesity [high body mass index]) to evaluate the combined effects of at least three lifestyle factors and all-cause mortality. They revealed that, instead of focusing on single risk factors, addressing their combination can generate better results in abating the risk of disease at the individual level.

Grimani et al. (2019, pp. 1, 3, 9-10) conducted a systematic literature review and suggested that work-related outcomes (e.g. absenteeism, productivity, work performance, workability, and presenteeism[26]) can be positively influenced through workplace health promotion interventions targeted at nutritional behaviour and/or physical activity. These initiatives may affect combinations of individuals, the organisational structure, and the physical work environment.

Krekel et al. (2019, pp. 2, 12, 17, 33-35, 38-40) studied the relationship between four performance outcomes and employee well-being by a meta-analysis to judge whether improving the latter dimension is coupled with enhanced productivity. Employee satisfaction demonstrated a significant positive correlation with customer loyalty, employee productivity, and profitability, while staff turnover showed a significant negative correlation. In addition, a broader term (‘employees’ engagement’) extending beyond satisfaction provided similar results with the four performance

[25] Alias the HERO (Health Enhancement Research Organisation) study.
[26] Presenteeism refers to the lost productivity that occurs when employees are not fully performing their tasks owing to physical and/or mental problems like illness or other conditions.

indicators by confirming the universal nature of the importance of employee well-being for corporate performance. Furthermore, the study highlighted distinct variations in the correlation based on both industries and geographical regions.

Numerous studies deal with cardiovascular diseases and their impacts on the quality of life by determining connections between them. *Pinheiro et al*. (2019, pp. 1472-1473) concluded that self-reported health may be a complement to current approaches when identifying and treating cardiovascular risks.

Abandoning the selection of international articles, it is worth mentioning that the Budapest Management Review includes an investigation of the domain of improving employee well-being. *Péter et al.* (2013, p. 57) examined corporate activities focusing on the preservation of health and stated that micro- and small enterprises internalise health consciousness into their organisational culture. *Barna–Fodor* (2018, p. 8) investigated a gamified social solution and found that its use is apt for creating a better workplace atmosphere and integrating regular physical activity into the lifestyle of employees. *Kovács–Martos* (2018, pp. 39-40) determined five distinct patterns with significantly different well-being indices based on a test measuring optimism as a reaction to situations.

Finally, *Szabó–Juhász* (2019, pp. 157, 164, 166) examined workplace well-being programmes from the viewpoint of risk management. Stress, physical inactivity, presenteeism, overweight/obesity, and poor diet can be considered as major workplace health risk factors in Europe. Physical inactivity, stress, obesity, unhealthy diet, smoking, high blood sugar, high blood pressure, depression, and alcohol consumption are the most important risk factors, which reduce productivity. Corporate well-being programmes can lessen fluctuation plus improve employee morale and work atmosphere. For example, they can create values by enhancing health consciousness amongst employees, or in the form of reducing absence from work and presenteeism coupled with increasing productivity.

Following my research objective of finding ‘tangible’ and easily interpretable metrics resulting in more health consciousness and raising life expectancy with particular reference to Hungary, the Czech Republic, and Austria, the application of risk assessment in the interest of diminishing cardiovascular risks emerged as a possible research gap. Consequently, this article establishes the basics of an effective risk assessment tool contributing to societal prosperity by strengthening the preventive components of corporate well-being programmes. Accordingly, the study aims at the following:

– estimating cardiovascular risks by age, gender, and further relevant parameters (Research question 1: How can cardiovascular risks be modelled?),
– quantifying the impact of cardiovascular risks on life expectancy based on various health statuses (Research questions 2-3: What are the life expectancies calculated based on the 10-year probabilities of fatal cardiovascular diseases as alternative metrics? What is the estimated maximum gender- and age-specific gain in life expectancy between the two extreme cases by minimising cardiovascular risks?)

4.3. Method

An artificial neural network method (ANN) was designed in the statistical software IBM SPSS Statistics Version 25 to reproduce 10-year mortality rates due to fatal cardiovascular diseases. ANN is one of the machine learning methods that can be applied for regression. The multilayer perceptron (MLP) is a feedforward, supervised learning network that is a function of one or more predictors that minimises the prediction error of the dependent variable. (*IBM, 2016, pp. 607-616*)

The general architecture of MLP networks consists of the input layer, the hidden layer(s), and the output layer. SPSS restricts the number of possible hidden layers to two and offers the following activation functions:

a) Hyperbolic tangent: $f(x) = \tanh x = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}}$, /1/

b) Sigmoid: $f(x) = \frac{1}{1 + e^{-x}}$, /2/

c) Identity: $f(x) = x$. /3/

By introducing the notation: **x** vector of the predictors, p number of the independent variables, q number of the neurons in the 1st hidden layer, r number of the neurons in the 2nd hidden layer, f activation function of the hidden layer(s), g activation function of the output layer, y output, **w** matrix or vector of the synaptic weights (parameter estimates), b_0 scalar, and **b**, $\mathbf{b_1}$ or $\mathbf{b_2}$ vector of the parameter estimates for the biases (intercepts) in the 1st or 2nd hidden layer, the dependent variable for one hidden layer can be determined as follows: $y = g\left[\sum_{j=1}^{q} \mathbf{w}(\mathrm{j}) \cdot f\left(\sum_{i=1}^{p} \mathbf{w}(\mathrm{i,j}) \cdot \mathbf{x}(\mathrm{i}) + \mathbf{b}(\mathrm{j})\right) + b_0\right]$ /4/

For two hidden layers, the additional layer renders the formula more complex:

$$y = g\left\{\sum_{k=1}^{r} \mathbf{w}(\mathrm{k}) \cdot f\left[\sum_{j=1}^{q} \mathbf{w}(\mathrm{j,k}) \cdot f\left(\sum_{i=1}^{p} \mathbf{w}(\mathrm{i,j}) \cdot \mathbf{x}(\mathrm{i}) + \mathbf{b_1}(\mathrm{j})\right) + \mathbf{b_2}(\mathrm{k})\right] + b_0\right\} \quad /5/$$

Modelling mortality is composed of two main steps: first, determining the mortality rates, and second, calculating the life expectancies as realisable gains. (*Office for National Statistics, 2021*)

Gender-specific mortality rates are divided into a cardiovascular component (*CV*) and a non-cardiovascular component (the remaining part unifying all other death causes; *nonCV*). Mortality rates are denoted by $q^{1\_A}_{x\_total}$, where A in the upper index represents the whole population comprising all health statuses; for this reason, they arise from a population life table. $q^{1\_A}_{x\_total}$ is the 1-year mortality rate, which is the probability that a person aged exactly x will die due to any cause of death before his/her $(x+1)^{\text{th}}$ anniversary. *S* refers to any single specific health status. By merging the two cases into one formula, we obtain

$$q^{1\_k}_{x\_total} = q^{1}_{x\_nonCV} + q^{1\_k}_{x\_CV},\ (k=\{A, S\}). \qquad /6/$$

As the non-cardiovascular component will generally be applied irrespective of health status, the values are calculated in the order below:

$$q^{1}_{x\_nonCV} = q^{1\_A}_{x\_total} - q^{1\_A}_{x\_CV}, \qquad /7/$$

$$q^{1\_S}_{x\_total} = q^{1}_{x\_nonCV} + q^{1\_S}_{x\_CV}. \qquad /8/$$

$q^{1\_k}_{x\_CV}$ is the 1-year mortality rate, which is the probability that a person aged exactly x will die due to cardiovascular diseases before his/her $(x+1)^{\text{th}}$ anniversary. $q^{1\_k}_{x\_CV}$ is determined as follows:

$$q^{10\_k}_{x\_CV} = q^{1\_k}_{x\_CV} + \sum_{i=1}^{9}\left(\prod_{j=0}^{i-1} p^{1\_A}_{x+j}\right)\cdot q^{1\_k}_{x+i\_CV},\ (k=\{A, S\}). \qquad /9/$$

The *t*-year survival rate $p^{t\_A}_{x}$, perceived in the whole population, is the probability that a person aged exactly x will reach the age x+t:

$$p^{t\_A}_{x} = 1 - q^{t\_A}_{x\_total}, \qquad /10/$$

$$p^{t\_A}_{x} = \prod_{j=0}^{t-1} p^{1\_A}_{x+j}. \qquad /11/$$

To track the specificities of the underlying mortality table, the equality of the quotient of death probabilities due to any reasons and cardiovascular diseases is assumed as follows:

$$\frac{q_{x\_total}^{1\_A}}{q_{x+9\_total}^{1\_A}} = \frac{q_{x\_CV}^{1\_k}}{q_{x+9\_CV}^{1\_k}},\ (k=\{A, S\}). \qquad /12/$$

By assuming a geometric series for the sake of simplicity, the rates at various ages at entry can be calculated:

$$q_{x+i\_CV}^{1\_k} = q_{x\_CV}^{1\_k} \cdot \left(\sqrt[9]{\frac{q_{x+9\_total}^{1\_A}}{q_{x\_total}^{1\_A}}} \right)^i,\ (k=\{A, S\},\ i=1, \ldots, 9). \qquad /13/$$

Cardiovascular mortality rates are generated based on the following equation derived from /9/ and /13/:

$$q_{x\_CV}^{1\_k} = \frac{q_{x\_CV}^{10\_k}}{1+\sum_{i=1}^{9}\left(\prod_{j=0}^{i-1} p_{x+j}^{1\_A}\right) \cdot \left(\sqrt[9]{\frac{q_{x+9\_total}^{1\_A}}{q_{x\_total}^{1\_A}}} \right)^i},\ (k=\{A, S\}). \qquad /14/$$

Owing to the lack of exact details, assumptions are introduced for estimating $q_{x\_CV}^{10\_A}$. First, symmetric distributions regarding systolic blood pressure (120, 140, 160, and 180 Hgmm) and total cholesterol (4, 5, 6, 7, and 8 mmol/l) are presumed (further details are provided under subsection 4.4. Data collection). Second, gender-specific smoking ratios are generally applied irrespective of age.

$e_x^{0\_k}$ denotes the remaining life expectancy at the exact age x, which is the average number of years that those aged exactly x will still live based on the k mortality rates.

$$e_x^{0\_k} = \frac{\sum_{i=x}^{\omega} L_i^k}{l_x^k},\ (k=\{A, S\}). \qquad /15/$$

L_x^k is the total number of years alive of l_x^k persons between the age x and x+1 by assuming that death cases occur linearly over a year:

$$L_x^k = \frac{l_x^k + l_{x+1}^k}{2},\ (k=\{A, S\}). \qquad /16/$$

l_x^k refers to the number of survivors aged exactly x of 100,000 live births (l_0=100,000) of the same sex who are assumed to be subject to the k mortality rates (k={A, S}) throughout their lives:

$$l_{x+1}^{k} = l_x^k \cdot \left(1 - q_{x\_total}^{1\_k}\right) = l_x^k \cdot p_x^{1\_k} = l_0 \cdot \prod_{i=0}^{x}\left(1 - q_{i\_total}^{1\_k}\right) = l_0 \cdot p_0^{x+1\_k}. \qquad /17/$$

$q_{100} = 1$ is assumed for each scenario (*A*, *S*) regarding both genders. The impact of ignoring cases above 100 years on life expectancy is negligible. The potential gain is the difference in life expectancy pertaining to the initial (S_0) and the more advantageous target health status (S_1): $e_x^{0\_S_1} - e_x^{0\_S_0}$.

4.4. Data collection

The model assumptions incorporate five domains:

1. 10-year mortality rates of fatal cardiovascular diseases, generated by the functions provided by the MLP,
2. population mortality rates,
3. smoking ratios,
4. death statistics due to cardiovascular diseases,
5. the population (i.e. the whole society) split by sex and age.

10-year mortality rates of fatal cardiovascular disease

Based on age-adjusted 2012 cardiovascular disease mortality rates, countries can be split into a group at high cardiovascular risk and that at low cardiovascular risk. For example, Hungary, the Czech Republic, and Poland fall in the former group while Austria, Germany, the United Kingdom, and Spain are low-risk countries given their more favourable rates. (*ESC, 2016, pp. 14-15*) The analysis covers both country groups so that the impact of future progress in abating cardiovascular rates in Hungary can be estimated.

Discrete values of the risk estimation for the occurrence of fatal cardiovascular events within 10 years are shown in Tables 1 and 2. These so-called SCORE (abbreviation for Systematic Coronary Risk Estimation) probabilities rely on five dimensions: gender (female [coded later with 2], male [1]), age (40, 50, 55, 60, and 65 years), smoker status (only binary: non-smoker [transformed later to 0], smoker [1]), systolic blood pressure (120, 140, 160, and 180 Hgmm), and total cholesterol (4, 5, 6, 7, and 8 mmol/l). Consequently, the total number of cases is 2·5·2·4·5=400 for both tables. (*ESC, 2016, p. 13*)

Table 1. Probabilities for the occurrence of fatal cardiovascular events within 10 years – countries at high cardiovascular risk (percentage) (*ESC, 2016, p. 13*)

Age	Non-smoker					Smoker					Systolic blood pressure (Hgmm)	Non-smoker					Smoker					Age
	4	5	6	7	8	4	5	6	7	8		4	5	6	7	8	4	5	6	7	8	
	Total cholesterol (mmol/l)											Total cholesterol (mmol/l)										
	Females											Males										
65	7	8	9	10	12	13	15	17	19	22	180	14	16	19	22	26	26	30	35	41	47	65
65	5	5	6	7	8	9	10	12	13	16	160	9	11	13	15	16	18	21	25	29	34	65
65	3	3	4	5	6	6	7	8	9	11	140	6	8	9	11	13	13	15	17	20	24	65
65	2	2	3	3	4	4	5	5	6	7	120	4	5	6	7	9	9	10	12	14	17	65
60	4	4	5	6	7	8	9	10	11	13	180	9	11	13	15	18	18	21	24	28	33	60
60	3	3	3	4	5	5	6	7	8	9	160	6	7	9	10	12	12	14	17	20	24	60
60	2	2	2	3	3	3	4	5	5	6	140	4	5	6	7	9	8	10	12	14	17	60
60	1	1	2	2	2	2	3	3	4	4	120	3	3	4	5	6	6	7	8	10	12	60
55	2	2	3	3	4	4	5	5	6	7	180	6	7	8	10	12	12	13	16	19	22	55
55	1	2	2	2	3	3	3	4	4	5	160	4	5	6	7	8	8	9	11	13	16	55
55	1	1	1	1	2	2	2	2	3	3	140	3	3	4	5	6	5	6	8	9	11	55
55	1	1	1	1	1	1	1	2	2	2	120	2	2	3	3	4	4	4	5	6	8	55
50	1	1	1	2	2	2	2	3	3	4	180	4	4	5	6	7	7	8	10	12	14	50
50	1	1	1	1	1	1	2	2	2	3	160	2	3	3	4	5	5	6	7	8	10	50
50	0	1	1	1	1	1	1	1	1	2	140	2	2	2	3	3	3	4	5	6	7	50
50	0	0	1	1	1	1	1	1	1	1	120	1	1	2	2	2	2	3	3	4	5	50
40	0	0	0	0	0	0	0	0	1	1	180	1	1	1	2	2	2	2	3	3	4	40
40	0	0	0	0	0	0	0	0	0	0	160	1	1	1	1	1	1	2	2	2	3	40
40	0	0	0	0	0	0	0	0	0	0	140	0	1	1	1	1	1	1	1	2	2	40
40	0	0	0	0	0	0	0	0	0	0	120	0	0	1	1	1	1	1	1	1	1	40

Table 2. Probabilities for the occurrence of fatal cardiovascular events within 10 years – countries at low cardiovascular risk (percentage) (*ESC, 2016, p. 14*)

Age	Non-smoker					Smoker					Systolic blood pressure (Hgmm)	Non-smoker					Smoker					Age
	4	5	6	7	8	4	5	6	7	8		4	5	6	7	8	4	5	6	7	8	
	Total cholesterol (mmol/l)											Total cholesterol (mmol/l)										
	Females											Males										
65	4	5	6	6	7	9	9	11	12	14	180	8	9	10	12	14	15	17	20	23	26	65
65	3	3	4	4	5	6	6	7	8	10	160	5	6	7	8	10	10	12	14	16	19	65
65	2	2	2	3	3	4	4	5	6	7	140	4	4	5	6	7	7	8	9	11	13	65
65	1	1	2	2	2	3	3	3	4	4	120	2	3	3	4	5	5	5	6	8	9	65
60	3	3	3	4	4	5	5	6	7	8	180	5	6	7	8	9	10	11	13	15	18	60
60	2	2	2	2	3	3	4	4	5	5	160	3	4	5	5	6	7	8	9	11	13	60
60	1	1	1	2	2	2	2	3	3	4	140	2	3	3	4	4	5	5	6	7	9	60
60	1	1	1	1	1	1	2	2	2	3	120	2	2	2	3	3	3	4	4	5	6	60
55	1	1	2	2	2	3	3	3	4	4	180	3	4	4	5	6	6	7	8	10	12	55
55	1	1	1	1	1	2	2	2	3	3	160	2	2	3	3	4	4	5	6	7	8	55
55	1	1	1	1	1	1	1	1	2	2	140	1	2	2	2	3	3	3	4	5	6	55
55	0	0	1	1	1	1	1	1	1	1	120	1	1	1	2	2	2	2	3	3	4	55
50	1	1	1	1	1	1	1	2	2	2	180	2	2	3	3	4	4	4	5	6	7	50
50	0	0	1	1	1	1	1	1	1	1	160	1	1	2	2	2	2	3	3	4	5	50
50	0	0	0	0	0	1	1	1	1	1	140	1	1	1	1	2	2	2	2	3	3	50
50	0	0	0	0	0	0	0	0	1	1	120	1	1	1	1	1	1	1	2	2	2	50
40	0	0	0	0	0	0	0	0	0	0	180	0	1	1	1	1	1	1	1	2	2	40
40	0	0	0	0	0	0	0	0	0	0	160	0	0	0	1	1	1	1	1	1	1	40
40	0	0	0	0	0	0	0	0	0	0	140	0	0	0	0	0	0	1	1	1	1	40
40	0	0	0	0	0	0	0	0	0	0	120	0	0	0	0	0	0	0	0	1	1	40

Population mortality rates

Gender-specific mortality rates were collected from suitable mortality tables. The life expectancy at birth and the underlying mortality tables for the selected countries are summarised in Table 3. The years of mortality tables are in parentheses.

Table 3. Life expectancy at birth in Hungary, the Czech Republic, and Austria (*HCSO, 2020a, Tables 6.2.15-6.2.16; Czech Statistical Office, 2021b; Statistik Austria, 2021a*)

Country	Males	Females
Hungary (2019)	72.9 years	79.3 years
Czech Republic (2019)	76.3 years	82.1 years
Austria (2019)	79.5 years	84.2 years

Smoking ratios

Table 4 displays the gender-specific smoking ratios applied irrespective of age. The last available data are from 2014 or 2017. The years of data are in parentheses.

Table 4. Share of smokers (percentage of the population aged 15 years and over) (*OECD iLibrary, 2021, Figure 4.1*)

Country	Males	Females
Hungary (2014)	31.6	20.8
Czech Republic (2017)	22.6	14.5
Austria (2014)	26.5	22.1

Death statistics due to cardiovascular diseases

In this case, the selected year is 2019 for each country. According to the international classification of ICD-10 (International Statistical Classification of Diseases and Related Health Problems, 10th Revision), diseases of the circulatory system are assigned to the codes I00–I99. (*WHO, 2019*) Although the practices of statistical offices in disclosing the number of deceased persons are dissimilar in detail, the codes I00–I99 cover the following items:

- I00–I02 Acute rheumatic fever,
- I05–I09 Chronic rheumatic heart diseases,
- I10–I15 Hypertensive diseases,
- I20–I25 Ischaemic heart diseases,
- I26–I28 Pulmonary heart disease and diseases of pulmonary circulation,
- I30–I52 Other forms of heart disease,
- I60–I69 Cerebrovascular diseases,

- I70–I79 Diseases of arteries, arterioles, and capillaries,
- I80–I89 Diseases of veins, lymphatic vessels, and lymph nodes, not elsewhere classified,
- I95–I99 Other and unspecified disorders of the circulatory system.

The population split by sex and age

As the above-mentioned 10-year mortality rates due to fatal cardiovascular diseases do not consider country-specific phenomena, Hungarian (one of the countries at high cardiovascular risk) demographic statistics (*HCSO, 2020a, Tables 6.2.18-6.2.19, 2020b*) split by age group have served as a basis for comparison to validate partially the modelled number of deaths due to cardiovascular diseases. The product corresponding to the number of the Hungarian population and the estimated 1-year mortality rate due to fatal cardiovascular diseases was contrasted with the actual number of deaths at the aggregated level of age groups. The same estimations were conducted in the cases of the Czech Republic (*Czech Statistical Office, 2021a, 2021c*) and Austria (*Statistik Austria, 2021b-2021c*). The set of assumptions (population mortality rates of 2019, death statistics due to cardiovascular diseases in 2019, and the population split by sex and age) is consistent regarding Hungary and the Czech Republic as the initial population refers to the 31st of December 2018 (CZ) or 1st of January 2019 (HU) while this continuity is broken with respect to Austria (AT) because of the population data valid for the 31st of October 2018.

4.5. Data analysis

Even if the assumptions may be subject to limitations, they are comprehensive and ensure the calculations provide valuable findings. First, an adequate model for generating 10-year mortality rates due to fatal cardiovascular diseases was established through MLP for both country groups. Subsequently, mortality rates differentiated by health status were determined so that life expectancies could be calculated. After validating the results with fact statistics, adjustments were performed to address the prevailing country-specific phenomena.

4.6. Findings

Research question 1: How can cardiovascular risks be modelled?

The current model limited to selected discrete values was extended to a general prediction of the 10-year probability of fatal cardiovascular diseases by assuming four different model types for both country groups. Prior to the runs, age, systolic blood pressure, total cholesterol, and cardiovascular probabilities were standardised. The results shown below are based on them. Table 5 presents the outcomes of the runs by applying the whole sample (400-400 records, here simultaneously identical with the population) as a training dataset. The sum of squared errors is calculated as the sum of the squares of the differences between the original non-standardised SCORE probabilities (see Tables 1 and 2) and the non-standardised MLP predicted values, both sequences of numbers are expressed in percentages. The correlation is calculated from the same non-standardised values. The analysis begins with the countries at high cardiovascular risk and continues with the group at low risk following the same logic.

Table 5. Results of the models

Model type	Number of hidden layers	Activation function		Correlation (%)		Sum of squared errors[27]	
		Hidden layer	Output layer	High risk	Low risk	High risk	Low risk
1	1	tanh	Identity	99.83	99.66	64.48	41.03
2	2	tanh	Identity	99.81	99.71	73.97	35.11
3	1	Sigmoid	Identity	99.81	99.65	73.44	42.35
4	2	Sigmoid	Identity	99.73	99.66	102.86	40.87

In Table 5, model type 1 produces the best goodness of fit for countries at high cardiovascular risk: one hidden layer composed of four neurons with hyperbolic tangent activation function for the hidden layer and with identity activation function for the output layer. Contrary to the previous case, model type 2 is the most appropriate in the case of low cardiovascular risk: two hidden layers, the first consisting of four neurons, the second of three neurons, with hyperbolic tangent activation function for the hidden layers and with identity activation function for the output layer.

Figure 2 depicts the structure of the neurons while Table 6 summarises the parameter estimates for countries at high cardiovascular risk.

[27] The sum of the squared estimate of errors (residuals) is set to: $SSE = \sum_{j=1}^{n}(y_j - \hat{y}_i)^2$

Figure 2. Synaptic weights – countries at high cardiovascular risk

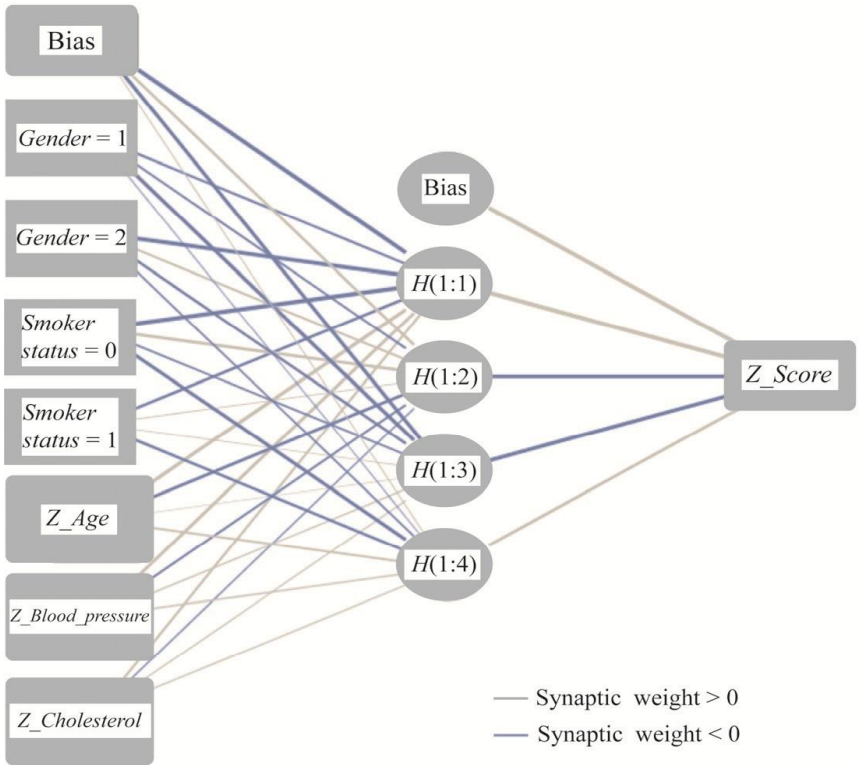


Table 6. Synaptic weights – countries at high cardiovascular risk

Predictor		Predicted				
		Hidden layer				Output layer
		H(1:1)	H(1:2)	H(1:3)	H(1:4)	Z_Score
Input layer	(Bias)	–1.457	0.639	–0.762	0.151	
	[Gender=1]	–0.351	–0.334	–0.777	–0.022	
	[Gender=2]	–1.425	0.387	–0.497	–0.272	
	[Smoker_status=0]	–1.578	0.662	–0.277	–0.730	
	[Smoker_status=1]	–0.502	0.036	0.023	–0.498	
	Z_Age	1.032	–0.643	0.021	0.349	
	Z_Blood_pressure	0.690	–0.345	0.238	0.248	
	Z_Cholesterol	0.391	–0.168	0.216	0.217	
Hidden layer	(Bias)					2.201
	H(1:1)					2.470
	H(1:2)					–1.223
	H(1:3)					–1.321
	H(1:4)					0.659

For countries at low cardiovascular risk, the structure of the neurons is illustrated in Figure 3 and the parameter estimates are reported in Table 7.

Figure 3. Synaptic weights – countries at low cardiovascular risk

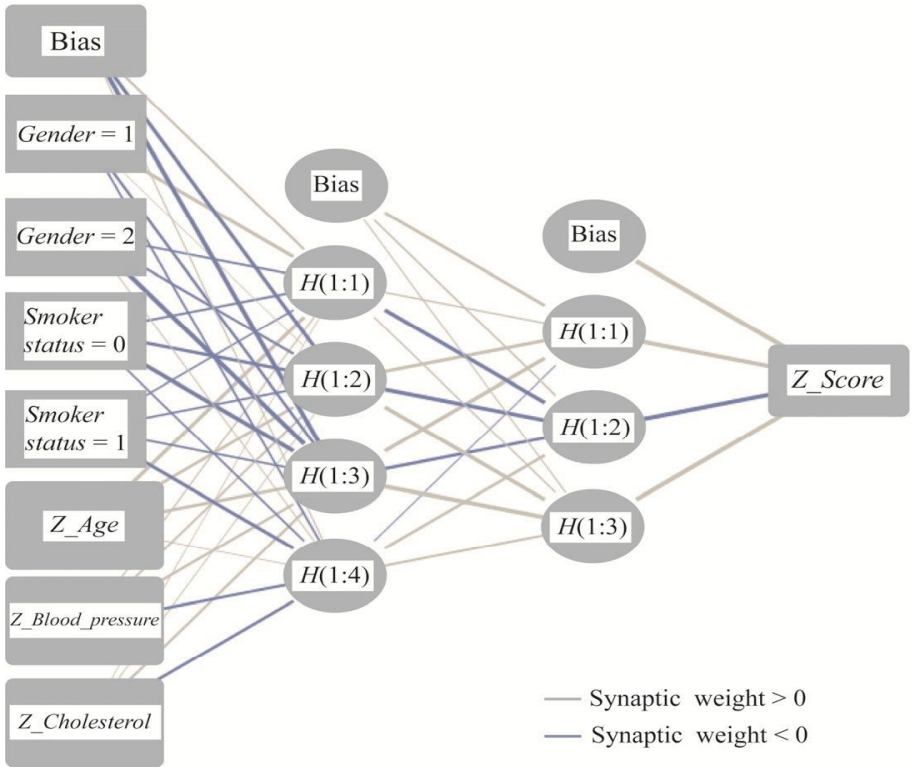


Table 7. Synaptic weights – countries at low cardiovascular risk

Predictor		Predicted			
		Hidden layer 1			
		H(1:1)	H(1:2)	H(1:3)	H(1:4)
Input layer	(Bias)	0.260	–0.592	–0.992	0.056
	[Gender=1]	0.641	0.003	–0.301	–0.119
	[Gender=2]	–0.213	–0.242	–1.076	0.035
	[Smoker_status=0]	–0.236	–0.537	–0.837	–0.106
	[Smoker_status=1]	–0.089	–0.163	–0.162	–0.548
	Z_Age	0.654	0.516	0.589	0.024
	Z_Blood_pressure	0.067	0.232	0.398	–0.382
	Z_Cholesterol	0.007	0.020	0.322	–0.452

Predictor		Predicted			
		Hidden layer 2			Output layer
		H(2:1)	H(2:2)	H(2:3)	Z_Score
Hidden layer 1	(Bias)	0.534	0.110	0.055	
	H(1:1)	0.102	–0.671	0.070	
	H(1:2)	0.605	–0.742	0.814	
	H(1:3)	0.688	–0.530	1.481	
	H(1:4)	–0.011	0.472	0.281	
Hidden layer 2	(Bias)				2.954
	H(2:1)				1.440
	H(2:2)				–1.054
	H(2:3)				1.882

According to Table 8, age is the most influencing factor on the 10-year probability of fatal cardiovascular diseases and gender ranks 3rd for both cases. Although fixed circumstances have a more deterministic role than factors on which individuals may exercise effects, considerable improvements can be achieved by mitigating cardiovascular risks by means of more health consciousness. Interestingly, by fixing age, all other determinants proved to be less highly ranked in low-risk countries compared to the high-risk states, presumably due to more developed health systems.

Table 8. Importance of the independent variables – comparison between countries at high and low cardiovascular risk

Independent variable	Importance of the independent variables		Normalised importance (%)	
	High risk	Low risk	High risk	Low risk
Gender	0.168	0.148	44.2	36.8
Smoker_status	0.120	0.125	31.7	31.0
Z_Age	0.380	0.402	100.0	100.0
Z_Blood_pressure	0.207	0.211	54.4	52.6
Z_Cholesterol	0.125	0.115	32.9	28.5

Research questions 2-3: What are the life expectancies calculated based on the 10-year probabilities of fatal cardiovascular diseases as alternative metrics? What is the estimated maximum gender- and age-specific gain in life expectancy between the two extreme cases by minimising cardiovascular risks?

The life expectancies of the best (non-smoker, 120 Hgmm systolic blood pressure, 4 mmol/l total cholesterol; denoted by index *B*) and the worst health status (smoker, 180 Hgmm systolic blood pressure, 8 mmol/l total cholesterol; identified by index *W*) were modelled between the age of 40 and 65. The maximum potential gain is the difference between the life expectancy calculated with the best mortality rates $q_{x\_total}^{1\_B}$ and that calculated with the worst rates $q_{x\_total}^{1\_W}$ based on the 10-year cardiovascular mortality rates $q_{x\_CV}^{10\_B}$ and $q_{x\_CV}^{10\_W}$.

Table 9. Potential gains in life expectancy by minimising cardiovascular risks based on Hungarian mortality rates and smoking ratios (years)

Age	Females				Males			
	Basic	Best	Worst	Gain	Basic	Best	Worst	Gain
40	40.1	42.6	35.8	6.8	34.1	38.1	28.4	9.8
45	35.4	37.8	30.9	6.9	29.5	33.4	23.9	9.5
50	30.7	33.1	26.3	6.8	25.1	28.9	19.9	9.0
55	26.2	28.6	22.1	6.5	21.1	24.7	16.3	8.4
60	22.0	24.3	18.3	6.0	17.6	20.9	13.5	7.4
65	18.1	20.2	14.9	5.3	14.5	17.5	11.5	6.0

Note: Basic (whole population)= e_x^{0-A}, best= e_x^{0-B}, worst= e_x^{0-W}, and gain= $e_x^{0-B} - e_x^{0-W}$.

For testing the validity of the 1-year cardiovascular mortality rates for the whole population, aggregated Hungarian demographic statistics are available at the level of age groups. Table 10 splits the aggregate of 63,609 death cases into subcategories by indicating the underlying diseases of the circulatory system.

Table 10. Number of deceased persons due to diseases of the circulatory system in Hungary, 2019 (*HCSO, 2020a, Tables 6.2.18-6.2.20; HCSO e-Shelf, 2021, Table 2.1; WHO, 2019*)

Cause of death	Males	Females	Total	Share (%)
Hypertensive diseases	3,525	6,284	9,809	15.4
– Essential (primary) hypertension	774	1,644	2,418	3.8
– Hypertensive heart disease	2,149	3,444	5,593	8.8
– Hypertensive renal disease	244	484	728	1.1
– Hypertensive heart and renal disease	358	712	1,070	1.7
Ischaemic heart diseases	14,587	17,083	31,670	49.8
– Acute myocardial infarction	3,301	2,398	5,699	9.0
– Chronic ischaemic heart disease	11,197	14,582	25,779	40.5
– Other ischaemic heart disease	89	103	192	0.3
Other forms of heart disease	3,391	3,479	6,870	10.8
Cerebrovascular diseases	4,981	6,507	11,488	18.1
– Intracerebral haemorrhage	879	769	1,648	2.6
– Cerebral infarction; occlusion and stenosis of cerebral arteries, not resulting in cerebral infarction	2,103	2,657	4,760	7.5
– Other cerebrovascular disease	1,999	3,081	5,080	8.0
Atherosclerosis	956	1,421	2,377	3.7
Other disorders of the circulatory system	704	691	1,395	2.2
Total	*28,144*	*35,465*	*63,609*	*100.0*
Population, 1 January 2019	4,675,821	5,096,935	9,772,756	–

The number of deaths split by age group was determined. Table 11 contrasts the real data with the estimated number of deceased persons as the product of the mortality rates $q_{x\_CV}^{1\_A}$ relying on Hungarian life tables and the number of Hungarian population aged x. As the ratios between fact and estimate substantially deviate from 100%, these

ratios were applied as multipliers to amend the assumption of symmetric distribution in such a way that the modelled results can be reconciled with the fact data. The results after adjustment are presented in Table 12.

Table 11. Actual deaths due to cardiovascular diseases in Hungary in 2019 and respective estimated values based on Hungarian mortality rates and smoking ratios

Age group	Actual CVD deaths		Estimated CVD deaths		Actual/estimated CVD deaths (%)	
	Males	Females	Males	Females	Males	Females
40–44	288	74	380	46	76	161
45–49	520	154	605	135	86	114
50–54	901	254	1,015	295	89	86
55–59	1,433	489	1,677	606	85	81
60–64	2,731	1,118	3,429	1,378	80	81
65–69	3,614	1,850	4,294	1,929	84	96
70–74	3,708	2,664	4,463	2,321	83	115
75–79	4,266	4,721	4,335	3,016	98	157
80–84	4,145	7,318	3,362	3,623	123	202
85–89	3,874	8,753	3,076	4,703	126	186
90–	2,473	8,003	5,701	14,604	43	55
Total	*27,953*	*35,398*	*32,337*	*32,654*	86	108

Note: CVD deaths mean deaths due to cardiovascular diseases. The estimated CVD deaths are rounded values, which explains the alteration in their indicated sum of 32,654 from the expected value of 32,656 after addition.

Table 12. Potential gains in life expectancy by minimising cardiovascular risks based on Hungarian mortality rates and smoking ratios, after adjustment with the multipliers (years)

Age	Females				Males			
	Basic	Best	Worst	Gain	Basic	Best	Worst	Gain
40	40.1	43.4	36.2	7.2	34.1	37.4	28.0	9.4
45	35.4	38.6	31.4	7.2	29.5	32.7	23.6	9.1
50	30.7	33.9	26.8	7.1	25.1	28.2	19.6	8.7
55	26.2	29.5	22.6	6.9	21.1	24.1	16.1	8.0
60	22.0	25.2	18.8	6.4	17.6	20.4	13.3	7.1
65	18.1	21.2	15.6	5.7	14.5	17.1	11.3	5.8

Note: Basic (whole population)= e_x^{0-A}, best= e_x^{0-B}, worst= e_x^{0-W}, and gain= $e_x^{0-B} - e_x^{0-W}$.

Following the same procedure, the investigation continues with the Czech Republic.

Table 13. Potential gains in life expectancy by minimising cardiovascular risks based on Czech mortality rates and smoking ratios (years)

Age	Females				Males			
	Basic	Best	Worst	Gain	Basic	Best	Worst	Gain
40	42.8	45.3	37.8	7.4	37.6	41.8	30.8	11.0
45	38.0	40.5	33.0	7.5	32.9	37.0	26.5	10.6
50	33.3	35.7	28.4	7.4	28.4	32.3	22.4	9.9
55	28.6	31.0	24.0	7.0	24.0	27.8	18.8	9.1
60	24.2	26.4	20.0	6.5	20.0	23.4	15.5	7.9
65	19.9	22.0	16.3	5.7	16.3	19.3	12.9	6.4

Note: Basic (whole population)= e_x^{0-A}, best= e_x^{0-B}, worst= e_x^{0-W}, and gain= $e_x^{0-B} - e_x^{0-W}$.

Table 14 divides the aggregate of 47,393 death cases due to diseases of the circulatory system into subcategories. The more favourable prevalence of these illnesses in the Czech Republic is remarkable.

Table 14. Number of deceased persons due to diseases of the circulatory system in the Czech Republic, 2019 (extract) (*Czech Statistical Office, 2021a, 2021c; WHO, 2019*)

Cause of death	Males	Females	Total	Share (%)
Hypertensive diseases	1,487	2,436	3,923	8.3
Ischaemic heart diseases	11,197	11,139	22,336	47.1
– Acute myocardial infarction	2,259	1,534	3,793	8.0
– Chronic ischaemic heart disease	8,621	9,428	18,049	38.1
– Other ischaemic heart disease	317	177	494	1.0
Other forms of heart disease	4,541	5,120	9,661	20.4
Cerebrovascular diseases	3,218	4,201	7,419	15.7
Atherosclerosis	684	851	1,535	3.2
Other disorders of the circulatory system	1,201	1,318	2,519	5.3
Total	*22,328*	*25,065*	*47,393*	*100.0*
Population, 31 December 2018	5,244,194	5,405,606	10,649,800	–

Table 15 contrasts the real data with the estimated number of deceased persons to determine the multipliers for adjustment. Table 16 contains the results after adjustment.

Table 15. Actual deaths due to cardiovascular diseases in the Czech Republic in 2019 and respective estimated values based on Czech mortality rates and smoking ratios

Age group	Actual CVD deaths		Estimated CVD deaths		Actual/estimated CVD deaths (%)	
	Males	Females	Males	Females	Males	Females
40–44	154	55	455	56	34	97
45–49	309	103	707	155	44	66
50–54	497	138	1,053	300	47	46
55–59	802	268	1,505	527	53	51
60–64	1,508	552	2,771	1,056	54	52
65–69	2,485	983	4,212	1,733	59	57
70–74	3,417	1,976	5,067	2,405	67	82
75–79	3,444	2,949	4,464	2,632	77	112
80–84	3,421	4,239	3,789	3,056	90	139
85–89	3,604	6,431	3,418	4,025	105	160
90–94	2,006	5,288	1,641	3,115	122	170
95–	517	1,988	667	2,089	78	95
Total	*22,164*	*24,970*	*29,748*	*21,149*	75	118

Note: The estimated CVD deaths are rounded values, which explains the alteration in their indicated sum of 29,748 from the expected value of 29,749 after addition.

Table 16. Potential gains in life expectancy by minimising cardiovascular risks based on Czech mortality rates and smoking ratios, after adjustment with the multipliers (years)

Age	Females				Males			
	Basic	Best	Worst	Gain	Basic	Best	Worst	Gain
40	42.8	45.8	37.8	8.0	37.6	39.7	29.7	10.0
45	38.0	41.0	33.0	8.1	32.9	35.0	25.4	9.6
50	33.3	36.3	28.3	8.0	28.4	30.5	21.4	9.1
55	28.6	31.7	24.0	7.7	24.0	26.1	17.9	8.3
60	24.2	27.2	20.1	7.1	20.0	22.0	14.7	7.3
65	19.9	23.0	16.6	6.4	16.3	18.2	12.3	5.9

Note: Basic (whole population)= e_x^{0-A}, best= e_x^{0-B}, worst= e_x^{0-W}, and gain= $e_x^{0-B} - e_x^{0-W}$.

Finally, as one of the countries at low cardiovascular risk, Austria is examined. The relationship between the corresponding values of Tables 9, 13, and 17 shows a more favourable situation in the Czech Republic than in Hungary while Austria surpasses both not only regarding the life expectancy at birth (see Table 3) but also later in life.

Table 17. Potential gains in life expectancy by minimising cardiovascular risks based on Austrian mortality rates and smoking ratios (years)

Age	Females				Males			
	Basic	Best	Worst	Gain	Basic	Best	Worst	Gain
40	44.9	46.8	41.4	5.4	40.7	43.2	36.3	6.9
45	40.0	41.9	36.6	5.3	35.9	38.4	31.7	6.7
50	35.2	37.1	31.9	5.2	31.3	33.7	27.4	6.3
55	30.6	32.4	27.4	4.9	26.8	29.0	23.2	5.8
60	26.0	27.7	23.2	4.6	22.5	24.6	19.5	5.1
65	21.6	23.2	19.2	4.1	18.5	20.3	16.3	4.0

Note: Basic (whole population)= e_x^{0-A}, best= e_x^{0-B}, worst= e_x^{0-W}, and gain= $e_x^{0-B} - e_x^{0-W}$.

Similar to the case of Hungary, these preliminary results without adjustment should be treated with reservations. The previous procedure was repeated, and Tables 18-20 highlight the results for Austria. Based on the share of ischaemic heart diseases and cerebrovascular diseases, the order of countries (Austria has the lowest proportion, thus AT<CZ<HU) is inverse to that determined in the case of life expectancy (HU<CZ<AT).

Table 18. Number of deceased persons due to diseases of the circulatory system in Austria, 2019 (extract) (*Statistik Austria, 2021b-2021c*)

Cause of death	Males	Females	Total	Share
Ischaemic heart diseases	7,076	6,260	13,336	41.48
– Acute myocardial infarction	2,582	1,744	4,326	13.46
– Other ischaemic heart disease (including chronic ischaemic heart disease)	4,494	4,516	9,010	28.03
Other forms of heart disease	2,635	3,914	6,549	20.37
Cerebrovascular diseases	1,969	2,764	4,733	14.72
Total	*14,335*	*17,813*	*32,148*	*100.00*
Population, 31 October 2018	4,351,670	4,499,747	8,851,417	–

Note: The source does not allow a more detailed presentation of death cases. Thus, the total sum deviates from the sum of the indicated categories.

Table 19. Actual deaths due to cardiovascular diseases in Austria in 2019 and respective estimated values based on Austrian mortality rates and smoking ratios

Age group	Actual CVD deaths		Estimated CVD deaths		Actual/estimated CVD deaths (%)	
	Males	Females	Males	Females	Males	Females
40–44	51	24	128	9	40	259
45–49	151	44	298	61	51	73
50–54	266	99	549	166	48	60
55–59	450	153	871	328	52	47
60–64	678	214	1,128	522	60	41
65–69	866	414	1,503	807	58	51

(*Table continues on the next page*.)

Age group	Actual CVD deaths		Estimated CVD deaths		Actual/estimated CVD deaths (%)	
	Males	Females	Males	Females	Males	Females
70–74	1,303	758	1,851	1,081	70	70
75–79	2,218	1,562	2,410	1,460	92	107
80–84	2,450	2,473	1,848	1,404	133	176
85–89	2,986	4,452	1,903	2,101	157	212
90–94	2,136	4,884	2,883	6,640	74	74
95–	697	2,706	988	3,609	71	75
Total	*14,252*	*17,783*	*16,360*	*18,188*	87	98

Table 20. Potential gains in life expectancy by minimising cardiovascular risks based on Austrian mortality rates and smoking ratios, after adjustment with the multipliers (years)

Age	Females				Males			
	Basic	Best	Worst	Gain	Basic	Best	Worst	Gain
40	44.9	46.6	41.3	5.3	40.7	42.3	35.7	6.6
45	40.0	41.8	36.5	5.2	35.9	37.6	31.1	6.4
50	35.2	37.0	31.9	5.1	31.3	32.9	26.8	6.1
55	30.6	32.3	27.4	4.9	26.8	28.4	22.8	5.6
60	26.0	27.7	23.2	4.6	22.5	24.1	19.2	4.9
65	21.6	23.4	19.3	4.1	18.5	20.0	16.1	3.9

Note: Basic (whole population)= e_x^{0-A}, best= e_x^{0-B}, worst= e_x^{0-W}, and gain= $e_x^{0-B} - e_x^{0-W}$.

The free-to-download tables (A1-A3) of the online Annex to this study (see http://www.ksh.hu/statszemle_archive/en/2021/2021_01/2021_01_017_annex.xlsx) align the life expectancies for each health status by applying a positive approach compared to the practice of relying on the mortality rates due to cardiovascular diseases. Each table enables individuals to select a starting and a target health status for a given combination of gender, age, smoker status, systolic blood pressure, and total cholesterol. Instead of operating with death probabilities, communicating life expectancies and the realisable accrual in life expectancy can be more motivating for eliminating behavioural risks. The results confirm that the statement regarding the order of countries (HU<CZ<AT) based on life expectancy can be generalised to each health status.

4.7. Discussion

Opting for ANN was an appropriate choice for reproducing the 10-year cardiovascular mortality rates and filling in the missing values between 40 and 65 years and beyond. The worst 10-year cardiovascular mortality rates above 65 years are reported in Table 21 and demonstrate a reasonable fit to Tables 1 and 2 for both risk types.

Table 21. Probabilities for the occurrence of fatal cardiovascular events within 10 years – estimations from 70 years (percentage)

Age	High risk		Low risk	
	Females	Males	Females	Males
	Estimation			
95	55	57	31	31
90	55	57	31	31
85	54	57	31	31
80	51	56	30	31
75	45	55	27	30
70	35	52	21	29
	Actual			
65	22	47	14	26

After adjusting the cardiovascular mortality rates, plausible life expectancies could be calculated for each combination of gender, age, smoker status, systolic blood pressure, and total cholesterol, which can serve as tailored arguments for stimulating commitments to a healthier lifestyle. By focusing on the two extreme cases regarding the investigated health statuses, Hungarian women aged 40 years can count on an additional 7.2 years. For men of the same age, the figure is 9.4 years. Ageing entails the shrinking of these indicators. At the age of 65, the increments amounting to 5.7 years for women and 5.8 years for men are still considerable and convincing for a change in habits. The inhabitants of the Czech Republic can benefit from 8.0, 10.0, 6.4, and 5.9 years, respectively. Compared to the two members of the Visegrád Four, Austria qualifies as one of the countries at low cardiovascular risk, which is manifested in lower values. The forecast is 5.3 years for 40-year-old females and 6.6 years for males. On reaching 65 years, the augmentation in life expectancy wanes to 4.1 and 3.9 years, respectively.

Figures 4 and 5 illustrate the life expectancies for the best health status and the gains in life expectancies between the best and worst health statuses. Figure 5 highlights the fact that better cardiovascular rates do not counterbalance the gender gap in the three countries, hence, Hungarian females may benefit from longer life expectancy than Austrian males.

Figure 4. Country comparison: life expectancies for the best health status split by gender

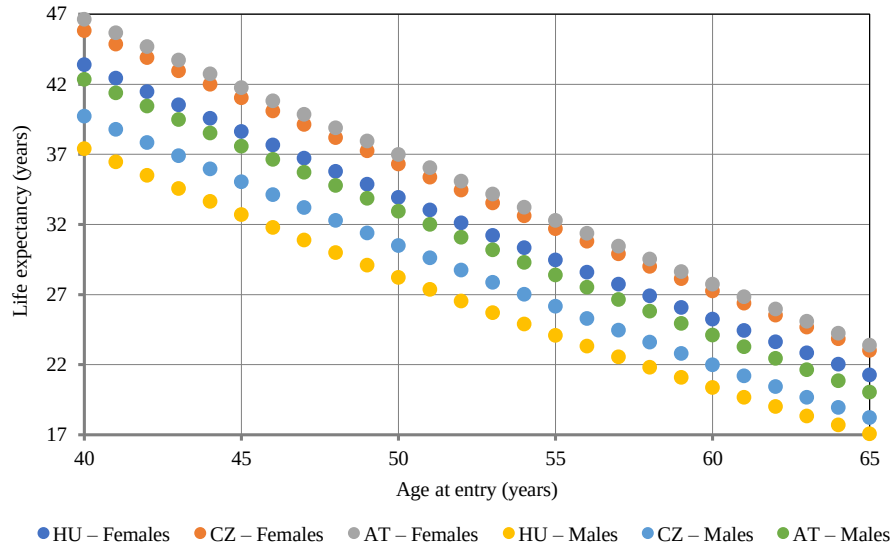
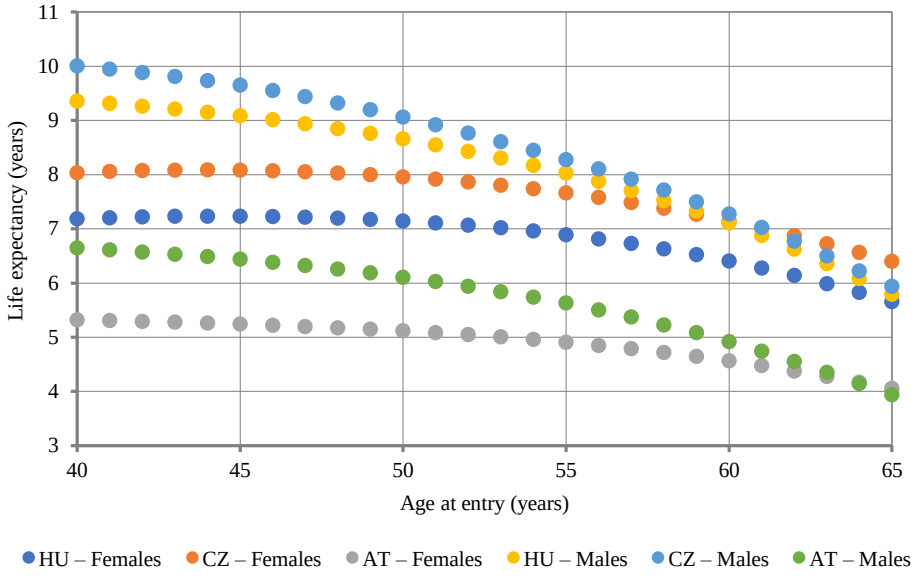


Figure 5 emphasises that Czech males can realise the highest gains up to 60 years. They are closely followed by Hungarian men. On the other side of the figure, Austrian females can achieve the lowest accrual, which is reasonable in view of their starting point of the longest life expectancy.

Figure 5. Country comparison: gains in life expectancies between the best and worst health statuses split by gender



4.8. Conclusion, limitations, and further research

This study revealed that prevention of the major death causes can be supported by an effective risk assessment tool. As the first step, ANN provided an appropriate model for generating mortality rates due to cardiovascular diseases for each individual based on gender, age, smoker status, systolic blood pressure, and total cholesterol. Subsequently, adjustment of these probabilities enabled the reproduction of actual death cases by involving country-specific circumstances and more prudent and plausible life expectancies could be determined. The differences in life expectancy between an initial health status and an envisaged health status are easy to communicate and understand, hence, they can be widely applied. Furthermore, the use of such tools is not coupled with resource-intensive requirements, which can accelerate their spread.

Nevertheless, the applied method has some limitations. Risks arising from cardiovascular diseases may depend on supplementary risk factors in addition to the five involved dimensions. Furthermore, as the dataset was restricted to 40-65 years, ages below and above the range could not be validated. The adjustment of probabilities was carried out only at the level of age groups. The combination-specific survival rates may differ from the applied general ones; however, the results (i.e. the potential gains as differences) are prudent as life expectancies pertaining to better health statuses are underestimated while those of worse life expectancies are overestimated. In addition to life expectancies, health statuses can be translated into healthy life expectancies, which can provide more insights into the risks inherent in lifestyles. Finally, given the lack of more detailed public life expectancy calculations, a comparison between the combination-specific results of the present study and figures provided by statistical offices could not be achieved.

Future research may extend the risk assessment tool by investigating other risk types so that involving them can enhance the effectiveness of prevention. Table 22 reveals mortality data by causes of death in Hungary, which can enable the identification of the areas where interventions are needed.

Table 22. Mortality by the group of causes of death in Hungary, 2019 (*HCSO e-Shelf, 2021, Tables 1.1, 2.1*)

Group of causes of death	Number of deaths	Share (%)
Infectious and parasitic diseases	686	0.53
Neoplasms	32,638	25.18
Diseases of the circulatory system	63,609	49.08
Diseases of the respiratory system	8,315	6.42
Diseases of the digestive system	6,354	4.90
Accidents	3,576	2.76
Suicides	1,550	1.20
Other	12,875	9.93
Total	*129,603*	*100.00*
Population, 1 January 2019	9,772,756	–

The country comparison outlined in Table 23 points to a presumed phenomenon that within the country group at high risk, improving effective primary prevention and public health care (e.g. shifting from the Hungarian values to the Czech ones) may result in more harvestable gains for individuals striving towards the best health status. On obtaining the low cardiovascular rates and passing into the eminent country group (here the comparison between the Czech Republic representing an interim phase and Austria), the general system-level improvement provides more realisable increments for individuals in less favourable health statuses. Further research may find evidence for this phenomenon.

Table 23. Country comparison: life expectancies and difference in life expectancies between countries (Czech Republic–Hungary, Austria–Czech Republic; [years])

Country	Age	Life expectancy				Difference in life expectancy			
		Females		Males		Females		Males	
		Best	Worst	Best	Worst	Best	Worst	Best	Worst
Hungary	40	43.4	36.2	37.4	28.0				
	65	21.2	15.6	17.1	11.3				
Czech Republic	40	45.8	37.8	39.7	29.7	2.4	1.6	2.3	1.7
	65	23.0	16.6	18.2	12.3	1.8	1.0	1.2	1.0
Austria	40	46.6	41.3	42.3	35.7	0.8	3.5	2.6	6.0
	65	23.4	19.3	20.0	16.1	0.4	2.7	1.8	3.8

Cardiovascular risks can be mitigated by utilising simple measures. Quantifying risks in the form of life expectancy can ensure the stimulus for reducing risk factors represented by poor-quality diet, smoking, alcohol, or low physical activity. Integrating risk assessment tools into existing practices of corporate well-being programmes can

promote prevention with immediate effects for nearly zero costs while potentials can be unleashed to the benefit of stakeholders not only at the individual but also at the company and country levels. The maximum realisable gain through the prevention of cardiovascular diseases can result in additional (43.4–36.2=) 7.2 years for 40-year-old females and (37.4–28.0=) 9.4 years for males in Hungary while the respective figures are (45.8–37.8=) 8.0 years and (39.7–29.7=) 10.0 years in the Czech Republic, (46.6–41.3=) 5.3 years and (42.3–35.7=) 6.6 years in Austria. Elderly people of 65 years may benefit from (21.2–15.6=) 5.7[28] years (women) or (17.1–11.3=) 5.8 years (men) in Hungary, (23.0–16.6=) 6.4 years (women) or (18.2–12.3=) 5.9 years (men) in the Czech Republic, and from (23.4–19.3=) 4.1 years (women) or (20.0–16.1=) 3.9 years (men) in Austria.

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5. The outstanding role of digitalisation and environmental protection in enhancing corporate competitiveness

Hungarian Statistical Review. 2022. 5(2). pp. 30-53. 10.35618/hsr2022.02.en030

Abstract

This study aims to explore Hungarian industries and manufacturing branches demonstrating the highest air pollutant emission intensities, unifying digitalisation and environmental protection tools into comprehensive categories, and designating differentiating single attributes and categories of digitalisation and environmental protection regarding competitiveness. Few studies have explored the nexus between competitiveness, digitalisation, and environmental protection. This study applies the independent samples t-test, principal component analysis, and non-hierarchical cluster analysis. The critical industrial areas include energy supply, agriculture, and emission-intensive manufacturing branches (wood, paper, and printing; coke and refined petroleum products; chemicals and chemical products; rubber and plastic products; basic metals and fabricated metal products).

More competitive and typically small and medium-sized Hungarian companies are more intensely impacted by a shortage of qualified workforce that impedes their innovation activities compared to less competitive firms. Additionally, the more competitive group outperforms the other group in both digitalisation and environmental protection. However, achieving better competitiveness does not necessitate a higher performance in any of the two fields within the more competitive group.

Keywords: competitiveness, digitalisation, environmental protection

5.1. Introduction

In a rapidly changing world, and with the dawn of the Fourth Industrial Revolution, competitiveness has been redefined. The ability to adapt to fast-changing circumstances and the readiness to employ modern technologies are a few challenges that companies incessantly face. The market is increasingly transforming into a complex space, customers' expectations are rising, stringent regulations are in place, and a sustainable

development framework is narrowing firms' leeway. Within this context, this study focuses on digitalisation and environmental protection. Contrary to digitalisation, which introduces new perspectives with immense opportunities, expenditure on protecting nature – exceeding compulsory norms – is often considered by corporate decision-makers as an undesired premature cost without economic advantages. Striving to diminish environmental loads would be crucial as the global economy has become inconsistent with ecological conditions in the past decades. Further, climate change, as one of the planetary boundaries (i.e. resource limitations and ecological thresholds of the Earth), has become a significant topic of discussion worldwide. By opting for decarbonisation pathways, countries should be impelled to realise slopes in reducing greenhouse gases, which enable them to remain within Earth's ecological threshold. To alleviate the negative impacts of climate change, this study argues for deepening both digitalisation and environmental protection at the enterprise level.

The Competitiveness Research Centre (CRC) of the Corvinus University of Budapest has regularly published its findings in the domain of competitiveness of Hungarian small and medium-sized enterprises (SMEs) since 1996. The progress in the field of environmental protection can be captured merely from the fourth report released in 2010, whereas digitalisation appeared in 2019 as part of the sixth phase. The nexus between competitiveness, environmental protection, and digitalisation presents numerous research gaps. Corporate competitiveness comprises offering products to customers amidst accomplishing social norms in a manner that they are inclined to pay a price, resulting in higher profitability than that realised by competitors. A country's economy can be considered competitive if it can sustainably produce, use, and sell products and services within the framework of global competition by increasing the welfare of its citizens and the benefits of its production factors. (*Chikán et al., 2019a, p. 19*) In the widest sense – and in the economic context – digitalisation ranges from (i) the conversion of a process from an analogue format to a digital one without any different-in-kind changes through (ii) creating business models exploiting digital opportunities until (iii) their diffusion restructuring the entire system. (*Gartner, 2022*)

This article was actuated by disclosing conclusions that simultaneously improve the position of domestic companies and introduce amelioration to society and nature in the short term by moderating environmental harms and steering attention to the inherent potential for digitalisation. The favourable constellation of decisive corporate and market circumstances perceived in the circle of best-practice Hungarian companies may compel

their competitors and market players in other industries to adopt their methods. Three research questions (RQ) were formulated. After inventorying the industries and manufacturing branches most affected by air pollutant emission intensities (RQ1), an attempt was made to create principal components describing digitalisation and environmental protection using multiple variables (RQ2). Based on this, this study reveals the relationship between corporate competitiveness and progress in the field of both environmental protection and digitalisation by designating measures enabling the rise from the less to the more competitive company group (RQ3). Correspondingly, the main findings from principal component analysis (PCA) and cluster analysis establish the significance of practice: the list of emission-intensive industries and manufacturing branches, possible principal components of digitalisation and environmental protection, and the differentiating principal components regarding competitiveness complemented by distinguishing single attributes.

5.2. Literature review

One of the discourses pursued in management science journals is explicitly targeted at or potentially expandable to domestic SMEs by investigating them from various business, management, and organisational perspectives. This study aimed to join this series of articles by conducting a critical literature review to provide practice-oriented recommendations for stakeholders. As mentioned earlier, digitalisation has been in the limelight since 2019. Therefore, articles published from 2019 formed the basis of the review to align the most frequently explored research fields. The literature review aims to identify a possible research gap in the nexus between corporate competitiveness, environmental protection, and digitalisation.

Studies published in the Budapest Management Review (BMR) deal with almost all of the current business, management, or organisational issues, with a predilection for the evolving field of Industry 4.0, incorporating, amongst others, the following: the spread of its technologies *(Baksa et al., 2020a);* its practice by production units related to technology, strategy, and organisation *(Demeter et al., 2020);* related opportunities offered by pricing strategies *(Rekettye, 2020);* its interaction with digitalisation *(Freund et al., 2020; Ternai, 2020; Csizmadia et al., 2021).* This latter dimension furnished further RQs in the area of the effects of digitalisation projects on sustainability *(Diófási-Kovács, 2020)*, the relationship between information and communication technology (ICT) use

and environmental performance *(Diófási-Kovács–Nagy, 2020),* Artificial Intelligence (AI) technologies *(Danyi et al., 2020; Harmat–Pistrui, 2022),* the advancement of the digital resource system and the applied digital approach *(Gubán–Sándor, 2021),* determinants of digital transformation in the sales industry *(Gáti et al., 2021),* or the digital entrepreneurial ecosystem *(Komlósi et al., 2020).* Human resource management is a popular research field in the context of Industry 4.0 *(Keszey–Tóth, 2020; Abonyi et al., 2021),* digitalisation *(Baksa et al., 2020b; Csillag et al., 2020; Bencsik, 2021; Michalec et al., 2021),* and factors hindering the innovation activity of enterprises *(Kiss, 2021).*

External articles were reviewed in addition to the BMR. *Matolcsy* (2020) expounded in rough lines on how structural reforms can make Hungarian society and economy more competitive and sustainable. *Boikova et al.* (2021, p. 14) identified four factors when investigating competitiveness and its relationship with economic growth in the circle of European economies. These include macroeconomic stability, research–development–digitalisation, foreign direct investment, and trade openness. *Chikán et al.* (2022) scrutinised the relationship between firms' capabilities and competitiveness. In a previous study, the same editors highlighted that at least 80% of the companies considered production/services, sales, quality management, and logistics as activities with significant contributions to company performance. Conversely, 68% similarly evaluated environmental protection. *(Chikán et al., 2019b, p. 41) Csesznák–Wimmer* (2021, pp. 145-147) deduced that more responsive and competitive firms outpace those lagging behind in digital preparedness. According to the corporate phenomenon, *Cahyadi–Magda* (2021) indicated a positive relationship between each pair of digital readiness, innovation, and competitiveness at the country level.

Following my objective, identifying a bundle of easy-to-implement tools, with particular reference to Hungarian SMEs, is a possible research gap. Consequently, this study endeavours to provide statements contributing to corporate competitiveness, penetration of digitalisation, and environmental health through the spread of best practices. Based on the literature review and available data, three RQs were formulated. This study aims to disclose the following:

- First, how can industries and manufacturing branches be characterised and ranked in relation to each other in terms of their air pollutant emission intensities through the example of the Hungarian economy (using the statistics of the Hungarian Central Statistical Office) (RQ1)?

- Second, which set of measures is the most appropriate for dimension reduction by creating the principal components of digitalisation and environmental protection (by relying on the database of CRC) (RQ2)?
- Third, which of the single attributes (RQ3a) and principal components (RQ3b) in digitalisation or environmental protection can be considered differentiating in terms of competitiveness?

5.3. Method

Quantitative analyses were carried out on the basis of the available data.

RQ1 and RQ2: Answering these questions requires dimension reduction. Exploratory factor analysis is an appropriate multivariate method. This creates new factors that are uncorrelated linear combinations of the variables involved. Thus, PCA addresses both issues.

RQ3a: The prerequisites (tests of normality and homogeneity of variances) and tests of equality of means were performed in the case of RQ3a. Both the Kolmogorov–Smirnov and the Shapiro–Wilk tests are appropriate to determine whether the subsamples follow a normal distribution. If the prerequisites are fulfilled, both the independent samples t-test and one-way ANOVA are apt to test the equality of means.

RQ3b: Kolmogorov–Smirnov tests, independent samples t-tests, and cluster analysis (non-hierarchical cluster analysis, also known as k-means cluster analysis) were employed enabling the creation of relatively homogeneous company groups. Pearson correlation coefficients were determined for the interrelationship between variables to measure the linear correlation between the two datasets.

All calculations were performed using IBM SPSS Statistics Version 27 and Microsoft Excel. *(Szüle, 2016, pp. 9-32)*

5.4. Data collection

RQ1: To gain insights into the recent status of air pollution arising from the national economy, 20 industries and 13 branches of manufacturing were evaluated by involving 12 relevant air pollutant emission intensities based on the gross value added (GVA) by applying current prices. The intensities are uniformly expressed in kg/million HUF. In addition to carbon dioxide (CO_2, the selected data: carbon dioxide with emissions from

biomass), miscellaneous greenhouse gases can aggravate global warming. Dinitrogen oxide (N_2O), methane (CH_4), hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulphur hexafluoride (SF_6) can exacerbate the climate crisis due to their multiple global warming potential compared to carbon dioxide. Additionally, acidifying gases [nitrogen oxides (NO_X), sulphur oxides (SO_X), ammonia (NH_3)], ozone precursors [carbon monoxide (CO), non-methane volatile organic compounds (NMVOC)], and particulate matters [with a diameter of 10 μm or less (PM_{10}), or its subset: with a diameter of 2.5 μm or less ($PM_{2.5}$); as $PM_{2.5}$ forms part of PM_{10}, only the latter broader category was selected] damage human and environmental health and man-made capital. *(HCSO, 2021a)*

Data for creating emission intensities: Air pollutant emissions by branches (2018), GVA (2018) (current price) *(HCSO, 2020, 2021b)*

RQ2, RQ3a, and RQ3b: A survey measuring the competitiveness of Hungarian firms with more than 50 employees was conducted during 2018–2019 by the CRC with the participation of 234 enterprises operating in Hungary. In total, 209 entities remained in the final sample. The major industries include manufacturing (51%) and trade (24%), and ¾ of these companies are held by domestic private owners. The CRC dataset, incorporating approximately 2,700 variables, predominantly comprised nominal and ordinal scale variables. The survey aimed to identify the determinants of corporate competitiveness and the prevailing tendencies. *(Chikán et al., 2019b, p. 4)*

5.5. Data analysis

RQ1 and RQ2: Regarding the PCA, five prerequisites were considered:

(i) The relationship between the sample size (n) and the number of variables (p) is confined by the rule of thumb, n>5p.

(ii) If the value of the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy (MSA) is at least 0.5, the sample can be considered appropriate for PCA.

(iii) The null hypothesis of Bartlett's test of sphericity (the correlation matrix is an identity matrix – the variables are independent) can be rejected.

(iv) The diagonal of the anti-image correlation matrix contains the MSA for each variable, and applying the previous threshold of 0.5 can be utilised for omitting variables.

(v) If all communality values exceed 0.25 post-extraction, each variable can be part of the model.

Table 1. Prerequisites of the PCA

Denomination	Industries and manufacturing branches (RQ1)	Digitalisation (RQ2)	Environmental protection (RQ2)
Sample size (n)	33	209	209
Variables (p)	Case 1: 6, Case 2: 7	27	25
(i) n>5p	Fulfilled if p=6, violated if p=7	Fulfilled	Fulfilled
(ii) KMO	Fulfilled (each KMO≥0.5)		
(iii) Bartlett	Fulfilled (each p-value of 0.000)		
(iv) MSA	Fulfilled (each MSA≥0.5)		
(v) Communality	Fulfilled (all communality values exceed 0.25)		
Rotation method	Varimax with Kaiser Normalisation		

RQ1: First, restricting the investigation to the three major greenhouse gases – CO_2, CH_4, and N_2O – still captures 97.8% of the total greenhouse gas emissions in the case of the observed industries/branches. The set of variables is compiled via four steps by conducting the PCA on the dataset as shown in Table 2. The rotated component matrices are extractable from Table 3.

Table 2. Determining the set of variables

Step	Number of variables	KMO	Decision rule
1	After excluding the three greenhouse gases with the lowest share (HFC, PFC, SF_6): 9; n<5p	0.412	Taking the lowest MSA from the anti-image matrix: PM_{10}: MSA = 0.089
2	After excluding PM_{10}: 8; n<5p	0.462	Taking the lowest MSA from the anti-image matrix: CH_4: MSA = 0.097
3	After excluding CH_4: 7; n<5p	0.654	To ensure a clear structure, the rotated component matrix suggests discarding NO_X.
4	After excluding NO_X: 6; n>5p is fulfilled.	0.548	p=6 is reached; thus, the process is terminated.
Final set of the available molecules		CO_2, N_2O, SO_X, NH_3, CO, NMVOC	

Table 3. Interrelatedness between air pollutants and components (rotated correlation coefficients in parentheses)

Air pollutants	p=7 molecules		p=6 molecules	
	Component 1	Component 2	Component 1	Component 2
Greenhouse gases	N_2O (0.976)	CO_2 (0.967)	N_2O (0.971)	CO_2 (0.960)
Acidifying gases	NO_X (0.724) NH_3 (0.973)	NO_X (0.631) SO_X (0.965)	NH_3 (0.967)	SO_X (0.958)
Ozone precursors	NMVOC (0.780)	CO (0.637)	NMVOC (0.801)	CO (0.667)

RQ2: First, dimension reduction was performed to manage 52 variables of 11 components; six components pertain to digitalisation (see Table 4), and five are part of environmental protection (see Table 5).

RQ3a: A total of 322 nominal or ordinal scale variables were selected for single attributes. The prerequisites (tests of (i) normality and (ii) homogeneity of variances) and tests of equality of means were performed.

RQ3b: After the PCA, Kolmogorov–Smirnov tests and independent samples t-tests were performed to reveal the differentiating principal components. Finally, applying cluster analysis and calculating the Pearson correlation coefficients as alternative methods made it possible to draw conclusions regarding the relationships between corporate competitiveness and digitalisation or environmental protection.

5.6. Findings

RQ1: Figure 1 illustrates 20 industries. Those that may not be indicated (professional, scientific, and technical activities; public administration and defence, compulsory social security; education; human health and social work; arts, entertainment, and recreation; other services; activities of households as employers) can be found in the left lower corner in the proximity of information and communication.

Figure 1. Location of the 20 industries in the space of air pollutant components based on the regression component scores (p=6)

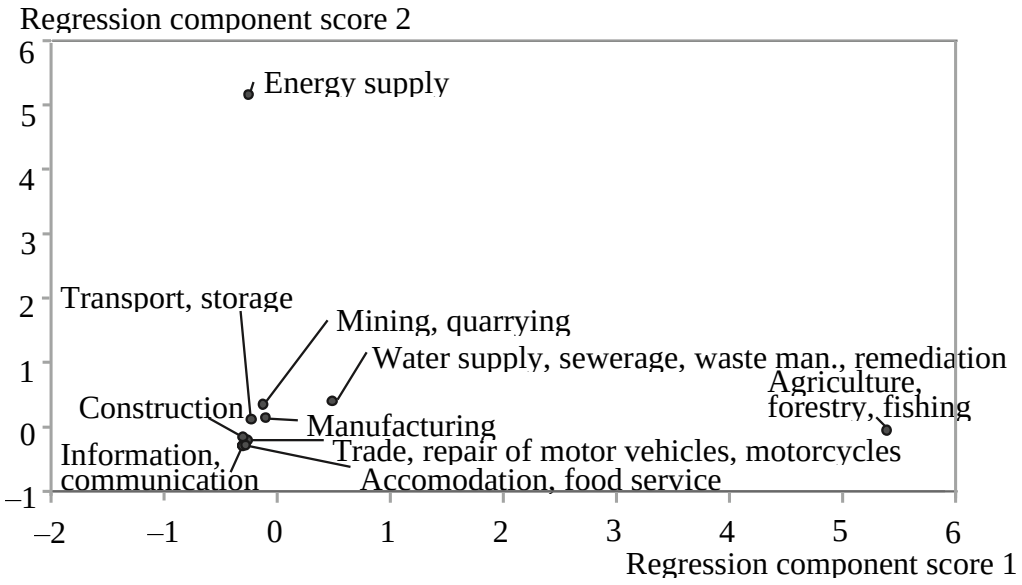
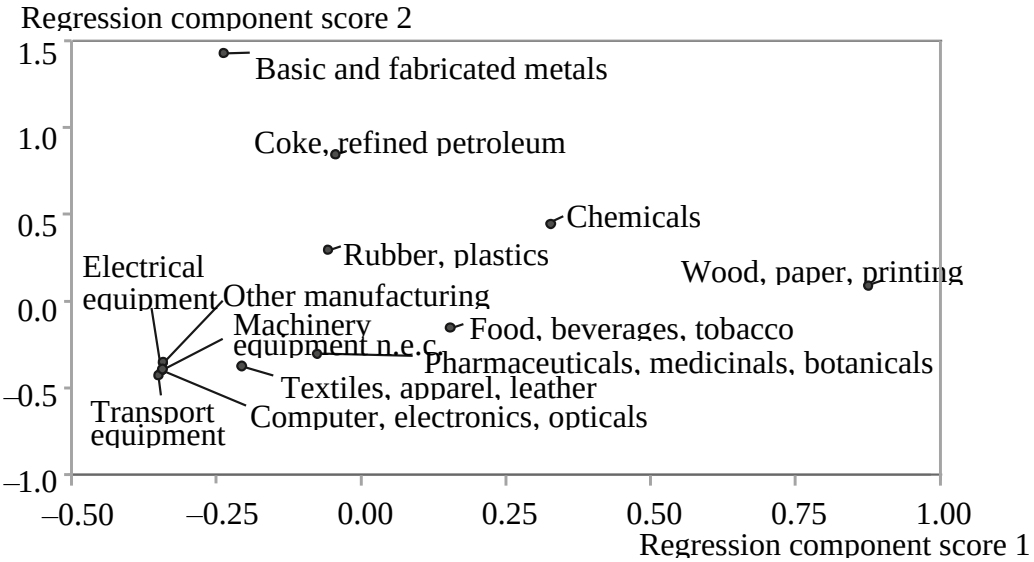


Figure 2. Location of 13 manufacturing branches in the space of air pollutant components based on the regression component scores (p=6)



The maps facilitate easy identification of the industries and manufacturing branches showing striking intensity in at least one of the components. The preponderance of the first component can be perceived in the case of agriculture, forestry, and fishing (largest N_2O, NO_X, NH_3, and NMVOC intensity) and the manufacture of wood and paper products and printing (less but still salient NMVOC and NO_X intensity). Conversely, the 2nd component dominates in energy supply, owing to the largest intensities of CO_2 and SO_X plus noteworthy NO_X and CO emissions. The same applies to the manufacture of

coke and refined petroleum products (CO_2, NO_X, and SO_X), rubber and plastic products and other non-metallic mineral products (CO_2, NO_X, and SO_X), and basic metals and fabricated metal products, except machinery and equipment (largest CO intensity, SO_X). Owing to the considerable intensities of CO_2, NO_X, SO_X, and NMVOC, both components prevail regarding the manufacture of chemicals and chemical products. The remaining industries and branches show lower emissions levels for the investigated air pollutants.

RQ2: Tables 4 and 5 tabulate the total variance explained by the components by exceeding 50% in each case.

Table 4. Total variance explained by the underlying component of digitalisation

Name of the component	Total variance explained (%)
Preparedness for digitalisation	73.780
Corporate level of digitalisation	71.325
Digitalisation applied by leading enterprises of the industry	83.596
Basic digitalisation tools	75.134
Advanced digitalisation tools	74.310
Technology use and change	50.147

Table 5. Total variance explained by the underlying component of environmental protection

Name of the component	Total variance explained (%)
Advanced environmental management tools	57.600
Basic environmental management tools	56.185
Environmental and social aspects of sustainability	65.244
Sustainability performance compared to competitors	79.219
Procurement	72.450

Tables 6 and 7 align the rotated correlation coefficients of the component matrices.

Table 6. Rotated correlation coefficients of the underlying component of digitalisation

Preparedness for digitalisation	
Management's understanding of challenges and opportunities	0.720
Clearly defined digital business strategy	0.820
Regulated digital transformation projects	0.810
Allocated sufficient financial resources	0.870
Availability of knowledge and abilities in technology	0.855
A free way for bottom-up digitalisation initiatives	0.888
Rapid digital solutions to challenges	0.899
Bearing risks coupled with innovative digital solutions	0.881
Tracking cutting-edge digital solutions of the industry	0.879
Conscious tentative use of technologies for testing their applicability	0.907
Outstripping competitors in digital technological innovations	0.902
Corporate level of digitalisation	
Digitalised operation	0.777
Automated processes	0.811
Built-in digital solutions	0.914
Internet of Things (IoT)	0.869
Digitalisation applied by leading enterprises of the industry	
Automated processes	0.847
Built-in digital solutions	0.940
IoT	0.953
Basic digitalisation tools	
Web shop (online sales)	0.867
Corporate social media tools	0.867
Advanced digitalisation tools	
Software robots	0.844
Big data	0.882
Predictive analytics	0.860
Technology use and change	
Technology as the main resource	0.820
Rapidly evolving technology	0.791
Contribution of ICT to corporate success	0.639
Applying automation and industrial robots	0.547

Table 7. Rotated correlation coefficients of the underlying component of environmental protection

Advanced environmental management tools	
Written environmental policy	0.729
Training in environmental protection for employees	0.646
Audit of environmental protection activities	0.780
Accounting system with entries about expenditures on environmental protection	0.813
Public environmental/sustainability/CSR report	0.813
Basic environmental management tools	
Measuring the performance of environmental protection activities	0.783
Applying environmental protection criteria in employee assessment	0.798
Measuring carbon dioxide emissions (carbon footprint)	0.660

Environmental and social aspects of sustainability	
Customers' perception of being an environmentally conscious/socially responsible company	0.812
Comparative advantages in environmental management practices	0.810
Mitigating business risks requires mitigating environmental protection risks	0.834
Offering products whose sales are meaningfully influenced by environmental protection/social aspects	0.794
Excelling in reshaping the industry along social and environmental aspects	0.891
Impacting the regulation of environmental protection affecting the industry	0.852
Operating in an ethical industry	0.744
Operating in a sustainable industry	0.716
Central role of sustainability in strategy-making	0.803
Sustainability performance compared to competitors	
Share of environmental protection from total expenditures	0.812
Water use per product unit	0.890
Material use per product unit	0.894
Waste generation per product unit	0.922
Energy use per product unit	0.895
Harmful emissions per product unit	0.922
Procurement	
Applying environmental protection criteria in procurement	0.851
Applying geographical distance when assessing procurers	0.851

RQ3a (single attributes): Only one item from the 322 variables in the areas of digitalisation and environmental protection proved to be differentiating regarding competitiveness between the more and less competitive firms (see Table 8). More competitive companies shared that the shortage of qualified workforce impeded their innovation activity between 2016 and 2018 more intensely compared to the less competitive group.

Table 8. Test results related to the shortage of qualified workforce (significance level)

Kolmogorov–Smirnov test H0: $X_1 \sim N(\mu_1, \sigma_1)$, $X_2 \sim N(\mu_2, \sigma_2)$	Homogeneity of variances (based on mean) H0: $Var(X_1)=Var(X_2)$	Independent samples t-test or one-way ANOVA H0: $\mu_1=\mu_2$
$p_1=0.200$, $p_2=0.200$	$p=0.942$	Less than 0.001

RQ3b (principal components): The Kolmogorov–Smirnov test confirms the normal distribution of both subsamples of company groups at a significance level of 5% for each principal component. Table 9 recapitulates whether the company groups can be

differentiated along the specific principal component by testing the null hypothesis of equality of means of company groups.

Table 9. Results of tests of homogeneity of variances and independent samples t-tests (significance level)

Name of the component	Levene's test for equality of variances H0: $Var(X_1)=Var(X_2)$	t-test for equality of means H0: $\mu_1=\mu_2$ (1) Equal variances assumed (2) Equal variances not assumed	Relationship between group means
Preparedness for digitalisation	0.202	(1) Less than 0.001	Different: $\mu_1\neq\mu_2$
Corporate level of digitalisation	Less than 0.001	(2) Less than 0.001	Different: $\mu_1\neq\mu_2$
Digitalisation applied by leading enterprises of the industry	0.023	(2) 0.153	No significant difference: $\mu_1=\mu_2$
Basic digitalisation tools	0.006	(2) Less than 0.001	Different: $\mu_1\neq\mu_2$
Advanced digitalisation tools	0.031	(2) 0.182	No significant difference: $\mu_1=\mu_2$
Technology use and change	0.051	(1) 0.004	Different: $\mu_1\neq\mu_2$
Advanced environmental management tools	0.398	(1) Less than 0.001	Different: $\mu_1\neq\mu_2$
Basic environmental management tools	0.442	(1) 0.927	No significant difference: $\mu_1=\mu_2$
Environmental and social aspects of sustainability	0.307	(1) Less than 0.001	Different: $\mu_1\neq\mu_2$
Sustainability performance compared to competitors	0.009	(2) Less than 0.001	Different: $\mu_1\neq\mu_2$
Procurement	0.047	(2) 0.001	Different: $\mu_1\neq\mu_2$

5.7. Discussion

RQ1: The circle of the identified industries and branches from the PCA encompasses energy supply, agriculture, forestry, and fishing, and five emission-intensive manufacturing branches (wood, paper, and printing; coke and refined petroleum products; chemicals and chemical products; rubber and plastic products; basic metals and fabricated metal products). This enumeration is partly on the list of difficult-to-decarbonise sectors requiring substantial efforts disclosed by the International Energy Agency, such as chemicals, iron and steel, cement, pulp and paper, and aluminium. *(IEA, 2020)*

RQ3a: More competitive companies shared that the shortage of qualified workforce impeded their innovation activity between 2016 and 2018 more intensely than the less competitive group.

Table 10. Summary of responses regarding the impact (ranging from 1 /slight/ to 5 /severe/) of shortage of qualified workforce on innovation activity

Company group	Share of smaller impact (1, 2, 3)	Share of larger impact (4, 5)	Number of respondents	Average
More competitive SMEs	40.230%	59.770%	87	3.621
Less competitive SMEs	65.574%	34.426%	61	2.852
More competitive large companies	⅖	⅗	20	3.700
Less competitive large companies	⅔	⅓	15	2.667
Not classified	N/A	N/A	26	
Total			209	

Note: N/A=not available or not applicable.

Although Hungary-specific proportions are not disclosed in the Digital Economy and Society Index (DESI) report, European Union figures depict the current trends and foreshadow those to be expected. Although ICT specialists accounted for 3.9% of total employment in 2018 in the EU-28, 64% of large enterprises and 56% of SMEs encountered difficulties due to the shortage of ICT specialists in the labour market while recruiting ICT specialists during the year. The DESI report does not detail the distribution based on competitiveness. Low levels of digital literacy cause the digital knowledge gap

perceived between SMEs and large companies regarding advanced technologies (e.g. AI, IoT, cloud computing, big data) and basic digital solutions (e.g. Enterprise Resource Planning, e-commerce). Assuming the extensibility of this gap along with competitiveness within SMEs, this conforms to the differentiating factors of corporate level of digitalisation (e.g. IoT), basic digitalisation tools (e.g. web shop), and technology use and change (e.g. rapidly evolving technology). However, it confutes the nature of advanced digitalisation tools (e.g. big data) being not distinguishing (see Table 9). According to the DESI report, only 17% of SMEs utilised Cloud Services (e.g. hosting of the database, customer relationship management), and 12% benefitted from big data analytics. *(DESI 2020, 2021, pp. 12-13, 51)* The CRC dataset produces similarities. A total of 19/172=11.047% of SMEs utilised big data, which nearly coincides with the DESI report. Large firms demonstrated a slight advancement, with 5/37=13.514%; nevertheless, a comparison with the DESI report is not ensured.

RQ3b: Although equality of group means cannot be rejected in the case of three principal components (advanced digitalisation tools, digitalisation applied by leading enterprises of the industry, and basic environmental management tools, as shown in Table 9), more competitive companies outperform the other group. This aligns with the finding from the CRC survey that a prerequisite of digitalisation, informatics, is declared mandatory for remaining competitive by 62% of the respondents. Informatics can ensure a competitive advantage for a short period (13% of the companies) or even longer duration (3%). *(Chikán et al., 2019b, p. 26) Csesznák–Wimmer* (2021, pp. 145-147) indicated a significant interrelatedness between competitiveness and digital preparedness, irrespective of the basic properties of firms (company size, owners, main activity, export orientation, etc.): those who are better at competitiveness outpace the laggards in digital preparedness as well. Surprisingly – and as partly outlined above – the component of advanced digitalisation tools missed being qualified as a differentiator. The latest achievements, such as predictive analytics, software robots, and big data, are rarely employed; in each case, 12-12% of the firms integrated them into their operations. *(Chikán et al., 2019b, p. 29)* Additionally, the null hypothesis of equal group means cannot be rejected in the case of digitalisation applied by leading enterprises of the industry. During 2006–2008, more than 40% of the companies in the CRC sample invested in environmental protection. It can be presumed that since then, thanks to the progress made over the last decade and a half, basic environmental management tools have become a must. *(Chikán et al., 2010, p. 33)*

To underpin the findings by an alternative method, similar to the Competitiveness Index, a comprehensive Technology Index was introduced based on the previous six principal components of digitalisation. Owing to the overlap, halved weights were assigned to components (2a) and (2b). The reason for the correction in (3a) and (3b) is that they are subsets of a common broader category. After these assumptions were made, an arbitrary choice was made for uniform distribution. Table 11 lists the weights used to unify the principal components of the Technology Index.

Table 11. Applied weightings for the Technology Index

Name of the component	Weighting (%)
(1) Preparedness for digitalisation	25.0
(2a) Corporate level of digitalisation	12.5
(2b) Digitalisation applied by leading enterprises of the industry	12.5
(3a) Basic digitalisation tools	12.5
(3b) Advanced digitalisation tools	12.5
(4) Technology use and change	25.0

By building the union of the subsamples, the Pearson correlation coefficient between the Technology Index and the standardised Competitiveness Index is weak at 0.289, and the p-value of the test of zero correlation is less than 0.001. The Pearson correlation coefficient is not significant in either group – they can be considered zero. This is in line with the presumed phenomenon that digitalisation does not entail the improvement of competitiveness in the more competitive group. Moreover, it does not explain the advancement in the less competitive group (see Table 12).

Table 12. Pearson correlation coefficients between the Technology Index built from the principal components and the standardised Competitiveness Index

Sample	Pearson correlation coefficient	Test of zero correlation (p-value)
Union of the subsamples	0.289	less than 0.001
More competitive group	0.051	0.598
Less competitive group	0.122	0.267

After the Technology Index, an analogous Environmental Protection Index for compressing the five principal components of environmental protection was created. Halved weights were assigned to components (1a) and (1b) as they are subsets of a

common broader category. For simplicity, equal weights were assigned to the components. Table 13 lists the arbitrarily selected weights for each specific part of the Environmental Protection Index.

Table 13. Applied weightings for the Environmental Protection Index

Name of the component	Weighting (%)
(1a) Advanced environmental management tools	12.5
(1b) Basic environmental management tools	12.5
(2) Environmental and social aspects of sustainability	25.0
(3) Sustainability performance compared to competitors	25.0
(4) Procurement	25.0

By merging the two groups, the Pearson correlation coefficient with the standardised Competitiveness Index is weak (0.380), and the p-value of the test of zero correlation is less than 0.001. Additionally, the assumption for the more competitive group is confirmed by an insignificant correlation, as the null hypothesis cannot be rejected. Nevertheless, at a significance level of 10%, the null hypothesis can be rejected for the less competitive group (see Table 14).

Table 14. Pearson correlation coefficients between the Environmental Protection Index built from the principal components and the standardised Competitiveness Index

Sample	Pearson correlation coefficient	Test of zero correlation (p-value)
Union of the subsamples	0.380	less than 0.001
More competitive group	0.070	0.465
Less competitive group	0.198	0.069

Alternative quantitative analyses were performed to verify the findings related to RQ3b. Commensurate with the specificities of the dataset, running a series of non-hierarchical cluster analyses could provide an alternative way of judging previous statements based on the final cluster centres; the results confirm and refute the findings partly. The group means underpin that – apart from advanced digitalisation tools, digitalisation applied by leading enterprises of the industry, and basic environmental management tools – accelerating digitalisation and/or environmental protection entails improved competitiveness when promoting from the less to the more competitive status. Within-group investigations provided the assumption that less competitive firms can

make progress in competitiveness with unfolding digitalisation. However, comparing the digitally better performing cluster with the most competitive cluster in the more competitive group clarifies the presumed phenomenon that other factors play a more crucial role beyond digitalisation in determining competitiveness. Interestingly, these conclusions elucidate that, beyond a certain level, competitiveness is not coupled with excelling in all the investigated dimensions of digitalisation. Similarly, intensifying environmental protection (apart from procurement) within the less competitive group is likely to be accompanied by an increase in competitiveness. Nevertheless, the contribution of enhanced environmental protection to competitiveness is not shown in the case of more competitive firms. Scrutinising the final cluster centres confirms the loose relationship determined by the Pearson correlation coefficients for the entire sample.

RQ1: Evaluating domestic industries and manufacturing branches by means of air pollutant emission intensities indicates the simultaneous reduction of emissions and the most critical areas: energy supply, agriculture, and five emission-intensive manufacturing branches (wood, paper, and printing; coke and refined petroleum products; chemicals and chemical products; rubber and plastic products; basic metals and fabricated metal products).

RQ2: Principal components of digitalisation incorporate preparedness for digitalisation, corporate level of digitalisation, digitalisation applied by leading enterprises of the industry, basic digitalisation tools, advanced digitalisation tools, and technology use and change. The principal components of environmental protection comprise basic environmental management tools, advanced environmental management tools, environmental and social aspects of sustainability, sustainability performance compared to competitors, and procurement.

RQ3a: More competitive companies are more intensely affected by a shortage of qualified workforce, impeding their innovation activity.

RQ3b: More competitive companies are better prepared for digitalisation, attain a higher level of digitalisation, and demonstrate the advanced application of basic digitalisation tools and technology. Further, they may undergo a technology change, build more on advanced environmental management tools, attribute greater significance to environmental and social aspects of sustainability, and outperform their competitors based on environmental indicators. Additionally, in these companies, environmental protection appears more definitely as a procurement criterion. Conversely, digitalisation applied by leading enterprises of the industry, instruments of advanced digitalisation, and

basic environmental management are not differentiating. Within-group investigations led to the assumption that less competitive firms can progress in competitiveness by unfolding any digitalisation or environmental protection components (except for procurement). Contrarily, if better group membership is attained, the positive impact of advancement in the principal components of competitiveness ceases to exist.

5.8. Conclusion, limitations, and further research

RQ1: The Hungarian Climate Protection Act (2020, XLIV) deals only with the abatement of greenhouse gas emissions. However, the analysis led to the findings that instead of addressing decarbonisation as isolated climate action, combining decarbonisation and elimination of other air pollutants should be prioritised by accentuating power generation, agriculture, and five emission-intensive manufacturing branches (wood, paper, and printing; coke and refined petroleum products; chemicals and chemical products; rubber and plastic products; basic metals and fabricated metal products). Industries and branches demonstrating the highest carbon dioxide intensity embody difficult-to-decarbonise sectors and areas with ample leeway for low-carbon technologies.

RQ2: Digitalisation can be captured by the possible set of six principal components: preparedness for digitalisation, corporate level of digitalisation, digitalisation applied by leading enterprises of the industry, basic digitalisation tools, advanced digitalisation tools, and technology use and change. Environmental protection can be divided into five subareas: basic environmental management tools, advanced environmental management tools, environmental and social aspects of sustainability, sustainability performance compared to competitors, and procurement.

RQ3a: For more competitive companies, the shortage of a qualified workforce is a hindering factor in the performance of innovation activities.

RQ3b: More competitive companies outperformed the less competitive ones in all investigated dimensions, except for digitalisation applied by leading enterprises of the industry, instruments of advanced digitalisation, and basic environmental management. The presumed within-group phenomena can be disclosed by splitting both groups into clusters. First, the positive impact of the principal components of competitiveness cannot be confirmed based on the more competitive group. Second, deepening digitalisation or

environmental protection (except for procurement) promotes the competitiveness of less competitive firms.

Each model has a few limitations. First, the results of the first PCA were influenced by the selected air pollutants. Given the limited number of variables, relevant air pollutants, such as methane and particulate matter, were removed from the model. Although carbon footprint facilitates a more accurate measurement of overall carbon dioxide emissions, data inadequacy rendered its utilisation impossible. Second, the database encompasses companies operating either in manufacturing (51%) or trade (24%), which is not representative of the structure of the national economy. Involving more industries could improve the applicability of the findings based on the second PCA. Third, achieving climate neutrality requires decoupling steady economic growth from greenhouse gas emissions. However, currently, the survey does not provide any information about greenhouse gas or carbon dioxide emissions. Augmenting the questionnaires with appropriate sections could facilitate future investigation of the propelling springs of digitalisation and estimating its potential for decarbonisation so that the penetration of digitalisation can be accelerated. By widening the scope of the questionnaires, the influencers of digitalisation may be revealed. Inventorying the common attributes may help overcome the hindrances perceived in the case of less competitive enterprises neglecting digitalisation in these dimensions and establishing the bases of openness and commitment to digitalisation. Another valuable extension of the questionnaire can be performed by proceeding from mere environmental protection to the circular economy.

As a broader outlook towards ecological economics, it is possible to provide full employment and high quality of life to all despite the Earth's limited resources and ecological thresholds. This research provides findings – as a slice of the toolkit leading to the accomplishment of this tenet – by recommending that SMEs take brisk steps towards both the scrutinised areas.

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6. Analysis of retail customers in the field of environmentally conscious behaviour with respect to home, mobility, heating and cooling, and governance[29]

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Abstract

This study aims to determine the factors to be improved to achieve a more elevated level of environmental awareness depending on the type of retail customers. By relying on the household survey conducted by the ENABLE.EU team with the purpose of identifying the drivers of individual energy choices and behaviours regarding home, mobility, heating and cooling, and governance, the findings widen the knowledge about environmentally conscious consumer behaviour. The dataset of the countries Hungary, Spain, and Ukraine served as a basis for the calculations. By addressing the research questions, both hierarchical and non-hierarchical cluster analyses, plus asymptotic independent samples z-tests were applied. The results reveal that the generalisability of environmental awareness can be declined: the most environmentally aware customers demonstrate a less conscious attitude in particular facets of mobility and governance. According to social and economic characteristics, this group is the most homogeneous, as it is composed of the most educated, economically active urban citizens with family and stable financial background. In the case of respondents lagging behind the best performers, a few favourable attitudes can be traced back to economic or demographic reasons. The findings enable decision-makers to conceive targeted approaches when raising awareness.

Keywords: environmentally conscious consumer behaviour, environmental awareness, sustainable consumption

[29] The study, conducted by the ENABLE.EU (Enabling the Energy Union) team between 2016 and 2019, examines the results of Hungary, Spain, and Ukraine from 11 European countries.

6.1. Introduction

Ensuring sustainable consumption and production patterns is one of the 17 Sustainable Development Goals (SDGs), part of the 2030 Agenda for Sustainable Development, which was adopted in 2015 in New York. (*United Nations, 2015, pp. 1, 14*) Although more than half of the planned period elapsed at the advent of 2024, advancements are still far from the time-proportionate requirements. Over and above this underperformance of progress towards the achievement of the SDGs, the current mainstream practices exacerbate climate change, biodiversity loss, and pollution of the environment. Focus areas are food waste, electronic waste, and the increasing exploitation of natural resources instead of moving towards the dematerialisation of the economy. The above-mentioned planetary problems represent severe threats to the SDGs, but responsible consumption is one of the means that can alleviate them by relying on the circular economy and ceasing excessive, careless resource use. (*United Nations–Department of Economic and Social Affairs, 2022, pp. 50-51*)

Decarbonisation targets lessening or removing greenhouse gases responsible for anthropogenic (i.e. originating in human activity) climate change. Instead of tackling it, preventive mitigation should be given priority so that the augmentation in global average temperature in the 21st century can be limited not only to the jointly accepted 2°C but preferably to 1.5°C relative to pre-industrial levels in accordance with the legally binding Paris Agreement, which is an international treaty in force after its ratification since 2016. (*United Nations, 2022*) The estimated potential of the energy and mobility turn is an 80 to 90% reduction in carbon dioxide emissions. (*Bild der Wissenschaft, 2019, p. 9*) Creating different scenarios beyond 1.5°C pathways enables decision-makers to assess the impacts and risks related to global warming. In the case of successful mitigation, the global surface temperature change until 2100 is projected to remain within the limit of 1.5°C. If an extreme scenario lacking both mitigation and adaptation is realised, the increase in global average temperature will be close to 5°C. Exacerbating the corollaries of increasing greenhouse gas emissions commensurately engenders harm to and damage in terrestrial, freshwater, and ocean ecosystems. Societies are likely to undergo climate-sensitive health outcomes, such as galloping heat-related morbidity and mortality. In addition to the general global perils, regional risks emerge, e.g. Africa will face aggravating food production from crops, fisheries, and livestock while loss and degradation will diminish coral reefs in Australia. (*IPCC, 2022, pp. 16-17*) Consequently,

by opting for decarbonisation pathways, countries should be urgently impelled to realise steeper slopes in the reduction of greenhouse gases, which enable them to remain within the ecological threshold. Worsening of many indicators (amongst others, Earth Overshoot Day, Living Planet Index, carbon dioxide concentration in Earth's atmosphere, share of urban population breathing air polluted by particulate matters, frequency of extreme weather events, quantity of plastic pollution in both fresh- and saltwater, intensity of deforestation) are omens hinting at deepening global crises.

Worldwide, the urban population compared to the total population reached 57% by 2021 and is expected to keep monotonously augmenting to approximately 70% by 2050. (*World Bank, 2022a-2022b*) Most countries are facing biocapacity deficits as their ecological footprint is exceeding their biocapacity. Although urbanisation may entail a larger urban ecological footprint than the average national ecological footprint (for instance, in the case of Athens, Barcelona, or Cairo), residents of cities have ample opportunities for diminishing their individual ecological footprint and its part, i.e. the carbon footprint. Globally, the carbon footprint equals 60% of the ecological footprint. The scope of means encompasses the nutritional habits of urbanites, the energy use of their households, their waste management, their personal transport, and the purchase of other goods and services. (*Global Footprint Network, 2015, pp. 22-23, 2023*) In particular, the per capita residential final energy consumption (without any kind of transport) in 2020 was 25.6 gigajoules in Hungary, 23.2 GJ in Poland, 21.3 GJ in Serbia, and 14.4 GJ in Bulgaria. Although the dissimilarities in the energy use of the households are partially due to systemic specificities at the national level or to climatic conditions, pro-environmental behaviour (e.g. in the field of heating and cooling) offers leeway for reduction. (*HCSO, 2022; Statista, 2022*)

This analysis attempts to identify the main manifestations of environmental awareness in the circle of retail customers based on their energy-related choices and behaviours. Hence, the objective is to provide applicable information about how to promote the penetration of environmentally friendly decisions in societies. Based on a dataset of the ENABLE.EU team, cluster analyses and concomitant asymptotic independent samples z-tests were performed to address the research questions (RQs). First, the routines of the most environmentally aware customers were inventoried by distinguishing between their strengths and weaknesses (RQ1). This served as a basis for further conclusions and recommendations. Second, the relationship between environmental awareness and socio-economic attributes was investigated (RQ2). The

significance of practice for decision-makers emerges in identifying the focus areas of environmental awareness depending on its current level, plus pointing to additional general social and economic areas that should be subject to measures when deciding how to heighten awareness.

6.2. Literature review

The critical review encompasses articles about environmentally conscious consumer behaviour and residential energy consumption in different countries, including comparative analyses.

Many authors have set up a theoretical model for exploring the linkages amongst ecologically conscious consumer behaviour and their influencers and tested it empirically. *Barbarossa–Pastore* (2015, pp. 188, 192, 195, 201) scrutinised a so-called green purchasing gap in the circle of 51 environmentally conscious Italian consumers. The gap captures the failure of exercising their positive attitudes towards the environment. By investigating the relationships amongst the most relevant barriers, the authors concluded that scarce availability, higher perceived prices, and improper mass media and in-store communication hinder green purchasing. The geographical scope of the cross-cultural study of *Raletić Jotanović et al.* (2016, pp. 561-562, 566-567) is the ex-Yugoslavian republics. On the one hand, the authors pointed to national differences in pro-environmental consumer behaviour amongst the involved countries; on the other hand, they found evidence that specific demographic and socio-economic characteristics such as educational level and the monthly income of the household influence environmental responsibility on the consumer level. In line with the previous findings, *Zalega* (2018, pp. 120-121, 124, 126, 129) derived statements valid for Polish seniors in the field of green consumerism by identifying the factors resulting in sustainable consumption patterns (gender, age, educational background, monthly disposable income, place of residence, and attending courses of the University of the Third Age at state universities). Nevertheless, the primary triggering motive of seniors is saving money, whereas environmental protection appears as a concomitant secondary advantage. This sheds light on the elevated price of eco-friendly solutions that restrains environmentally conscious consumer actions.

Craig (2016, p. 667) underlined the role of positive attitudes and behaviours related to energy efficiency in the energy consumption of residential electricity consumers.

Clients who are aware of energy efficiency programmes have more favourable perceptions about utility motives; in addition, they realise reductions in both consumption and emissions (i.e. by participating in programmes, supporting subsidies and clean energy use of utilities). *Eon et al.* (2018, p. 291) found in a sample of Australian houses that the energy use per square meter varied by up to 33%. Major determinants in energy use are, amongst others, the technology of heating and cooling systems installed in real estate, practices of heating and cooling, knowledge, and components of behaviour. *Kashour* (2023, pp. 47-48) examined pairwise the interrelatedness between residential energy consumption and the three components of the human development index at the country level for the member states of EU-27. The education index has no significant link to energy consumption while life expectancy has a negative impact and GNI has a positive impact.

Lake et al. (2017, p. 423) emphasised the advantage of district heating and cooling systems in the field of efficiency by comparing them with individual energy systems. They urged the spread of district energy. *Werner* (2017, pp. 617, 628) identified the major global hindrances of district heating and cooling systems. These are low and varying country-specific penetration of district heating in buildings, still mediocre commitment to district heating, lack of susceptibility to carbon dioxide emission reductions, and feeble general awareness of the district heating and cooling benefits. Nevertheless, district heating and cooling systems have future promising harvestable potential. *Ge et al.* (2018, p. 1139) pointed to the range of 3-15 years of the payback period of solar heating and cooling systems depending, amongst others, on components, geographic location, and subsidy. From an economic point of view, initial cost and allowance can influence the spread of these systems advantageously. *Chen et al.* (2022, p. 11) endeavoured to find the optimal heating and cooling system as a mixture of solar thermal, photovoltaics, and energy storage devices installed on different types of buildings. They stated that noteworthy energy savings and economic benefits can be realised; however, the cost of devices and the price of grid electricity are crucial factors. Finally, long-term forecasts attempt to project future energy use and its drivers (*Ürge-Vorsatz et al., 2015; Santamouris, 2016*).

Following my objective of providing easily implementable findings, the attributes of the most conscious customers from a broader perspective are a possible research gap. Consequently, this research endeavours to align statements contributing to enhancing environmental awareness by relying on the practices appertaining to various levels of

consciousness. The nexus between customers' behaviour and their socio-economic background creates an appropriate framework for the analysis. Based on the literature review and the available data, two RQs were formulated. This study aims to disclose the following:

- First, which characteristics describe the most environmentally aware customers and their less conscious counterparts by relying on the countries Hungary, Spain, and Ukraine and applying a commonly used standard for ensuring comparability? Ultimately, the overarching question emerges whether the most environmentally aware customers demonstrate excellence in each field. (RQ1)
- Second, which socio-economic phenomena prevail in Hungary regarding environmentally conscious consumer behaviour? (RQ2)

6.3. Method

Quantitative analyses were carried out.

RQ1: For identifying the most aware customers, cluster analyses (both hierarchical cluster analysis and non-hierarchical cluster analysis, the latter also known as k-means cluster analysis) enabling the creation of relatively homogeneous costumer groups were employed. After the cluster analyses, asymptotic independent samples z-tests were performed. They are apt to test the equality of means as – contrary to the prerequisites of independent samples z- or t-tests – neither the normal distribution of the samples nor the homogeneity of variances, merely finite standard deviations and large samples are required, which are ensured. (*Hunyadi et al., 2000, pp. 468-469*)

RQ2: Answering this question necessitates asymptotic independent samples z-tests.

Both hierarchical cluster analysis and non-hierarchical cluster analysis were performed in the statistical software IBM SPSS Statistics Version 29. (*Szüle, 2016, pp. 9-18*) The asymptotic independent samples z-tests were carried out in Microsoft Excel.

6.4. Data collection

Between 2016 and 2019, the ENABLE.EU team undertook a project with the purpose of disclosing the drivers of individual energy choices and behaviours with the participation of 11,265 retail customers from eleven countries (Bulgaria – 1,000 persons, France – 1,500, Germany – 711, Hungary – 1,022, Italy – 1,025, Norway – 1,221, Poland

– 1,000, Serbia – 1,000, Spain – 760, Ukraine – 1,011, and the United Kingdom – 1,015). The team compiled a questionnaire for conducting a household survey so that social and cultural influencing factors could be revealed. The survey comprises seven sections: home/building characteristics and household possessions, mobility, prosumers (etymologically, a prosumer unifies the producer and the consumer in one single individual), heating and cooling, electricity, governance, and social and economic characteristics. The dataset contains 473, predominantly nominal and ordinal scale variables. (*ENABLE.EU team, 2019*) Table 1 recapitulates the sections split by country.

Table 1. Dataset: available combinations of sections and countries

Country	Home	Mobility	Prosumers	Heating and cooling	Elec-tricity	Govern-ance	Socio-economic
Bulgaria	x	–	–	–	x	x	x
France	–	–	–	x	–	x	x
Germany	x	–	–	x	x	x	x
Hungary	x	x	–	x	–	x	x
Italy	x	x	x	–	–	–	x
Norway	x	x	x	–	–	x	x
Poland	x	x	–	–	–	x	x
Serbia	x	–	x	–	x	x	x
Spain	x	x	–	x	–	–	x
Ukraine	x	–	x	x	–	x	x
United Kingdom	x	–	x	–	x	x	x
Number of countries	10	5	5	5	4	9	11

RQ1: By selecting Hungary as an initial point, the datasets appertaining to the sections on home/building characteristics and household possessions, mobility, heating and cooling, plus governance bear importance for the comparative analysis of this study.

RQ2: The socio-economic conclusions rest on the section on social and economic characteristics.

6.5. Data analysis

Prior to applying the mentioned techniques, data transformation was performed. The rationale was relying on customer attitudes expressed with a few interval scale variables instead of applying numerous simple, from an ecological point of view relevant, ordinal scale variables indicated directly by customers in the course of the survey. Depending on the nature of the newly introduced variables, if a variable follows decreasing monotonicity, the lower the value is, the more conscious the customer is. In the case of increasing monotonicity, higher values entail more awareness. The statements

listed in the questionnaire can be considered either positive or negative. To unify the points given to statements of both types, either the positive or the negative statements were fixed depending on the underlying variable, and the opposite statements were transformed in such a way that their point was deducted from 6 or 5 because of the possible range between 1 and 5 or 4. Table 2 summarises the 19 variables used for the analysis by indicating their composition if the original variable was transformed.

Table 2. Set of the original and transformed variables (*ENABLE.EU team, 2019, pp. 5-26*)

Section	Name of the variable applied for the analysis [Brief description of the variable] /Monotonicity of favourable values/	Name of the original variables and their brief description
Home/ Building characteristics and household possessions	H12B [proportion of energy-efficient bulbs inside homes] /decreasing/	
	AGR_NEG_STAT [agreeing with negative statements about environmental issues] /decreasing/ AGR_NEG_STAT=H15A+H15B+H15C+ +(5–H15D)+H15E	H15A [refusing to act] H15B [environmental impacts being overstated] H15C [shifting problems to future generations] H15D [making compromises in current lifestyle] H15E [financial consequences of environmental policies]
Mobility	TIME_SHARE_PREF_MODE [time share of preferred travel modes] /increasing/ TIME_SHARE_PREF_MODE= $= \frac{\sum_{i=A}^{E}\left[\sum_{j\in j*} M3(i)2\_Time\_(j)\right] \cdot M1(i)}{\sum_{i=A}^{E}\left[\sum_{j=1}^{11} M3(i)2\_Time\_(j)\right] \cdot M1(i)}$	M1(i) [weekly number of days split by destinations, 5 variables] M3(i)2_Time_(j) [travel time split by travel mode, 11 variables] (i) is the index of the most frequent destinations, i={A, B, C, D, E} (j) is the index of the travel mode, j={1, 2, …, 11}, thereof preferred are j*=j\{1,4,11}
	TOT_DIST_PER_WEEK [total distance per week] /decreasing/ TOT_DIST_PER_WEEK= $= 2 \cdot \sum_{i=A}^{E} M1(i) \cdot M4(i)$	M1(i) [weekly number of days split by destinations, 5 variables] M4(i) [distance from home to destination in km split by destinations, 5 variables] (i) is the index of the most frequent destinations, i={A, B, C, D, E}
	ENV_FR_MOB [environmentally friendly mobility] /increasing/ ENV_FR_MOB=M5G+M5H	M5G [importance of air quality impact in decisions] M5H [importance of CO_2 emissions impact in decisions]
	SCORE_TRANS_SYS [score of supporting government actions affecting the transport system] /increasing/ SCORE_TRANS_SYS=$\sum_{i=C}^{H} M8(i)$	M8C [bike lanes and speed controls] M8D [tests and manufacturer emissions standards] M8E [faster public car-sharing and public transport] M8F [more attractive public transport] M8G [reducing transport distances] M8H [compressed workweeks and home office]
	SEV_TRAF_PROB [severity of traffic problems] /increasing/ SEV_TRAF_PROB=$\sum_{i\in\{A,B,C,D,F\}} M9(i)$	M9A [traffic congestion] M9B [traffic noise] M9C [excessive presence of vehicles] M9D [local air quality] M9F [global warming]

Section	Name of the variable applied for the analysis [Brief description of the variable] /Monotonicity of favourable values/	Name of the original variables and their brief description
Heating and cooling	BILL_INFORM_MOD [issues related to billing and the provided information about modernisation] /decreasing/ BILL_INFORM_MOD=C4D+C5A+C5C+ +(6–C6A)+(6–C6B)+(6–C6C)+(6–C6D)+ +(6–C7A)+(6–C7B)	C4D [payback of investment] C5A [regularity of feedback on energy consumption] C5C [interpretation of energy bills] C6A [comparative feedback on energy consumption] C6B [providing information on smart and easy techniques] C6C [frequency of measuring and billing] C6D [energy-saving tips and reminders for energy-saving actions] C7A [getting advice on energy savings from experts] C7B [advice on energy savings in the media]
	FIN_CONS_MOD_HIND [opportunities and difficulties emerging when financing the refurbishment and further hindrances of carrying out the modernisation] /decreasing/ FIN_CONS_MOD_HIND=C4A+C4B+C4C+ +C4E+C4F+C4K+C4L+C4M+(6–C7C)+ +(6–C7D)+(6–C7E)+(6–C7F)	C4A [lack of money for refurbishment or insulation] C4B [available loans with unfavourable conditions] C4C [missing subsidies for refurbishment] C4E [large dwelling with high heating costs] C4F [the owner differs from the tenant, missing willingness to save energy] C4K [difficulties caused by the dependence on all tenants] C4L [limitations coupled with old buildings] C4M [burdensome nature of renovations] C7C [financing the investment from energy savings] C7D [refurbishment at an affordable price due to the help of local actors] C7E [national energy efficiency grants and assistance] C7F [expanding energy subsidies programmes]
	COOL_HEAT_HAB_INF [cooling and/or heating habits plus their influencers] /decreasing/ COOL_HEAT_HAB_INF=C4G+C4H+C4I+ +C4J+(6–C5B)+(6–C5D)+(6–C5E)+C5F+ +C5G+C5H+C5I	C4G [being at home and heating during daytime] C4H [lack of individual metering] C4I [unworthiness of refurbishment in the case of old and inefficient dwellings] C4J [energy bill dependent on the consumption of other households] C5B [low and/or affordable amount of energy bills] C5D [heating with own garbage] C5E [seizing available energy-saving opportunities] C5F [not energy-conscious neighbours] C5G [forgotten control of the room temperature] C5H [postponing saving plans] C5I [neighbours heating with garbage]

Section	Name of the variable applied for the analysis [Brief description of the variable] /Monotonicity of favourable values/	Name of the original variables and their brief description
Govern-ance	LESS_ENERGY_CONS [less energy consumption thanks to environmentally friendly alternatives] /increasing/ LESS_ENERGY_CONS=G1A1+G1A2+G1A3	G1A1 [new car with low fuel consumption] G1A2 [walking, biking, public transport, car-sharing] G1A3 [more energy-efficient household appliances]
	AGR_INCONV_EFM [agreeing with the inconvenience arising from environmentally friendly measures] /decreasing/ AGR_INCONV_EFM=G5A+(6–G5B)+G5D	G5A [severe limitations in city centres for cars causing air pollution] G5B [affordability of renewable energy solutions] G5D [paying a higher price for electricity from renewable energy sources]
Social and eco-nomic charac-teristics	S1 [total number of persons living in the household for at least 6 months of the year] S1=S1Ac1+S1Ac2+S1Ac3+S1Bc1+S1Bc2+ +S1Bc3	S1Ac1 [women under the age of 18 years] S1Ac2 [women aged between 18 and 65 years] S1Ac3 [women older than 65 years] S1Bc1 [men under the age of 18 years] S1Bc2 [men aged between 18 and 65 years] S1Bc3 [men older than 65 years]
	S2 [highest level of completed studies]	
	S3 [current employment status]	
	S4 [year of birth]	
	S5 [gender]	
	S6 [type of area of residence]	
	S8 [category of household's current income]	

Example for the interpretation of Table 2: In the case of COOL_HEAT_HAB_INF, smaller values are better due to decreasing monotonicity. A low total score expresses the ease of reducing energy consumption and/or its costs while a higher total score hints at difficulties in their diminution.

RQ1: One of the limitations of the tremendous dataset (size: 11,265x473) is the presence of missing values, which restricts its usability. To overcome this deficiency, the original dataset was filtered to obtain solely full records in the section on heating and cooling, which selection enables the maximum number of records apt for analysis. For this reason, the variables BILL_INFORM_MOD, FIN_CONS_MOD_HIND, and COOL_HEAT_HAB_INF were applied for cluster analysis (see later in Table 3). In terms of the countries, Hungary, Spain, and Ukraine provide sufficient full records (HU: 569 full records from a total of 1,022 records, ES: 102 from 760, UA: 89 from 1,011), whereas France and Germany cannot meet this requirement (FR: 0 from 1,500, GE: 3 from 711). First, hierarchical cluster analysis was carried out on the dataset composed of the three countries to determine the presumed number of clusters. The result suggested by the dendrogram is 4 clusters by using the three interval scale variables, squared Euclidean

distance as a measure, and Ward's method as a cluster method with a cut value of 8 as a rule of thumb.

Second, k-means cluster analysis was carried out by applying k=4 and k=3. The ANOVA tables confirm that the participating clients diverge significantly based on each of the three variables. The numbers of customers split by clusters are enumerated in Table 3. Cluster 1 represents the most aware customers thanks to the lowest final cluster centres for each variable. The further clusters are not ordered based on environmental awareness.

Table 3. Results of the non-hierarchical cluster analyses: cluster sizes (the distribution is denoted in parentheses), 760 cases, 3 countries

Run	Cluster 1	Cluster 2	Cluster 3	Cluster 4
k=4	163 (21.45%)	141 (18.55%)	227 (29.87%)	229 (30.13%)
k=3	286 (37.63%)	203 (26.71%)	271 (35.66%)	–

Table 4 details the values of the three variables in a comparative way for both runs. The range is calculated as the product of the number of variables and the minimum (1) or the maximum (5) of the possible points. To underpin the subsequent findings, k=3 was chosen because it can ensure a higher cluster size due to the less stringent conditions – apart from COOL_HEAT_HAB_INF – of qualifying as a most environmentally aware customer.

Table 4. Final cluster centres, 760 cases, 3 countries

Name of the introduced variables	Range	Final cluster centres of Cluster 1	
		k=4	k=3
BILL_INFORM_MOD	9-45	21.88	24.93
FIN_CONS_MOD_HIND	12-60	24.63	26.19
COOL_HEAT_HAB_INF	11-55	24.45	24.36

Third, the variables of Table 2 render a more profound evaluation of environmentally conscious consumer behaviour possible. In addition to heating and cooling, the investigated fields encompass home, mobility, and governance as well. After excluding the records with at least one missing value in the supplementary nine variables of the mentioned sections, 480 cases remained from the original set of 760 records. A series of null hypotheses $(H_0: \bar{y} - \bar{x} = 0)$ with the one-sided alternative hypotheses $(H_1: \bar{y} - \bar{x} > 0)$ or $(H_1: \bar{y} - \bar{x} < 0)$ was carried out by dint of the formula of the asymptotic independent samples z-test:

$$Z = \frac{\bar{y} - \bar{x} - \delta_0}{\sqrt{\frac{s_Y^2}{n_Y} + \frac{s_X^2}{n_X}}} \rightarrow N(0,1)$$

On the one hand, $\bar{y}$ denotes the value in question of the most conscious customer group (Cluster 1), and $\bar{x}$ refers to the corresponding best or second-best value (Cluster 2 or 3); on the other hand, $\delta_0 = 0$. Under the square root stand variances (s^2) and sample sizes (n). (*Hunyadi et al., 2000, pp. 468-469*)

These tests reveal the variables testifying to a significant difference in means. Based on the differentiating factors, conclusions can be drawn with respect to practices where more advancement is recommended for raising awareness.

RQ2: To disclose the socio-economic phenomena amongst the clusters, seven variables (S1, S2, S3, S4, S5, S6, S8 from the section on social and economic characteristics, see Table 2) were involved in the asymptotic independent samples z-tests. On the one hand, country specificities (e.g. urbanisation, educational level of the population) may distort the results; on the other hand, neither Spain nor Ukraine have any valid full records; therefore, further scrutiny is restricted to Hungary. The non-hierarchical cluster analysis (k=3) provided the required sample sizes so that each Hungarian cluster could be qualified as a large sample. Table 5 illustrates the composition of 760 respondents divided into cluster-country combinations for both runs (k=4 and k=3). An additional 75.46% increment in the size of the best cluster argues for k=3.

Table 5. Number of cases split by cluster and country, k=4 and k=3, 760 cases, 3 countries

Country→/	Hungary		Spain		Ukraine		Total	
Cluster↓	k=4	k=3	k=4	k=3	k=4	k=3	k=4	k=3
Cluster 1	116	223	25	30	22	33	163	286
Cluster 2	129	171	5	6	7	26	141	203
Cluster 3	189	175	7	66	31	30	227	271
Cluster 4	135	–	65	–	29	–	229	–
Total	*569*		*102*		*89*		*760*	

6.6. Findings

RQ1: Which characteristics describe the most environmentally aware customers and their less conscious counterparts by relying on the countries Hungary, Spain, and Ukraine and applying a commonly used standard for ensuring comparability?

Table 6 derives the significance level (p-value) for each variable. If the value of the most conscious customer group (Cluster 1) is the most favourable, it is marked with bold font type while the corresponding best or second-best values of the remaining clusters are marked with italic font type.

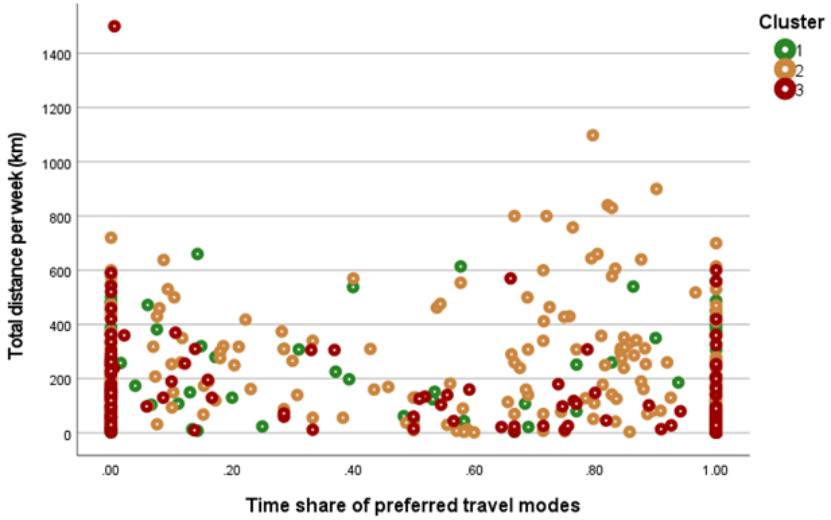
Table 6. Mean and standard deviation of the variables for each cluster (k=3), significance level of the asymptotic independent samples z-tests, 480 cases, only Hungary (missing cases excluded listwise)

Variable (better value)	Range	Cl. 1 Mean	Cl. 2 Mean	Cl. 3 Mean	Cl. 1 Std. dev.	Cl. 2 Std. dev.	Cl. 3 Std. dev.	z-test	p-value
H12B (lower)	1-5	**2.62**	*2.93*	3.01	1.25	1.55	1.48	-1.95	0.025
AGR_NEG_ STAT (lower)	5-20	**10.48**	11.09	*11.05*	2.16	2.51	2.24	-2.38	0.009
TIME_ SHARE_ PREF_MODE (higher)	0%-100%	50.74%	*63.32%*	54.53%	0.41	0.44	0.46	-2.62	0.004
TOT_DIST_ PER_WEEK (lower)	[km] 2-12,000	244.21	*120.87*	130.13	218.07	156.31	142.04	5.98	0.000
ENV_FR_ MOB (higher)	2-10	**8.06**	*6.91*	6.72	2.06	2.47	2.10	4.47	0.000
SCORE_ TRANS_ SYS (higher)	6-30	**22.11**	*21.27*	20.64	3.94	5.36	4.13	1.56	0.059
SEV_TRAF_ PROB (higher)	5-25	**16.96**	*16.56*	15.85	3.88	4.53	4.59	0.84	0.201
BILL_ INFORM_ MOD (lower)	9-45	**25.88**	33.71	*26.64*	4.58	3.88	3.20	-1.80	0.036
FIN_CONS_ MOD_HIND (lower)	12-60	**26.07**	37.17	*35.52*	3.89	5.53	4.76	-19.74	0.000
COOL_ HEAT_ HAB_INF (lower)	11-55	**24.01**	*28.77*	34.36	3.27	4.17	3.91	-11.17	0.000
LESS_ ENERGY_ CONS (higher)	0-3	0.59	*0.78*	0.70	0.72	0.61	0.69	-2.59	0.005
AGR_ INCONV_ EFM (lower)	3-15	9.83	9.83	*9.42*	2.00	2.13	1.75	2.02	0.022
Number of cases		191	138	151					

By assuming that the cluster indexed with 1 unifies the most environmentally aware customers amounting to 191 in Hungary, at a significance level of 5%, the null hypothesis can be declined for H12B, AGR_NEG_STAT, ENV_FR_MOB, BILL_INFORM_MOD, FIN_CONS_MOD_HIND, and COOL_HEAT_HAB_INF. At a significance level of 10%, the former list of variables is complemented with SCORE_TRANS_SYS. A significant difference in the case of SEV_TRAF_PROB cannot be underpinned.

Furthermore, the best cluster should be propelled to make advancements in the variables TIME_SHARE_PREF_MODE, TOT_DIST_PER_WEEK, LESS_ENERGY_CONS, and AGR_INCONV_EFM. Figure 1 illustrates that both Clusters 2 and 3 occupy a more favourable position than the most environmentally aware group.

Figure 1. Customers in the mobility aspect space



The position of Clusters 2 and 3 is ambiguous. The variables H12B, AGR_NEG_STAT, TOT_DIST_PER_WEEK, ENV_FR_MOB, SCORE_TRANS_SYS, and LESS_ENERGY_CONS proved to be not significant at a significance level of 10%. At a significance level of 10%, Cluster 2 outpaces the customers of the third group in two areas (SEV_TRAF_PROB, COOL_HEAT_HAB_INF), and it outdoes both other clusters in TIME_SHARE_PREF_MODE. In contrast, at a significance level of 5%, Cluster 3 surpasses Cluster 2 in BILL_INFORM_MOD and FIN_CONS_MOD_HIND while the third group ranks number one in AGR_INCONV_EFM.

The most environmentally aware customers replaced, on average, more than 50% of the old classic bulbs with energy-efficient bulbs in their homes. In addition, they can identify themselves mostly with environmental issues and excel in all dimensions of heating and cooling. Moreover, they attribute the most importance to air quality and CO_2 emissions when making decisions about mobility, and they testify to the most supportive attitude towards government actions ameliorating the transport system. Surprisingly, the most and less conscious customers perceive traffic problems to a similar extent. Finally, the most environmentally aware customers are recommended to achieve improvements in opting for more environmentally friendly alternatives concerning mobility (controversial to the mentioned concerns regarding air quality and CO_2 emissions) and

household appliances, moderating the travelled distance coupled with CO_2 emissions, and accepting environmentally friendly measures that may cause inconvenience for them. All things considered, the findings refute the generalisability (i.e. excellence in each field: home, mobility, heating and cooling, governance) of environmental awareness in the circle of retail customers. In the case of Cluster 2, a group can be identified that occupies an environmentally friendly position in mobility based on the means. Nevertheless, this cluster cannot be considered environmentally aware, as it underperforms in many scrutinised dimensions. (*ENABLE.EU team 2019, pp. 5-24*)

Apart from four variables (TOT_DIST_PER_WEEK, BILL_INFORM_MOD, LESS_ENERGY_CONS, AGR_INCONV_EFM), the group of the most environmentally aware customers can be considered the most homogeneous as being environmentally aware means reaching almost the same high level of awareness; thus, the criteria of environmental awareness can be narrower defined. The considerable within-group differences in Clusters 2 and 3 point to the broad range of levels representing less environmental awareness. Table 7 expounds the suggestions for ameliorating consumer behaviour by applying a significance level of 10%. Instead of applying an isolated approach, the overlapping dimensions argue for combining actions and merging clusters.

Table 7. Combinations of proposed actions and affected clusters based on Hungary, significance level = 10%

Variable [denomination]	Cluster 1	Cluster 2	Cluster 3
H12B [energy-efficient bulbs inside homes]	–	x	x
AGR_NEG_STAT [identification with environmental issues]	–	x	x
TIME_SHARE_PREF_MODE [opting for preferred travel modes]	x	–	x
TOT_DIST_PER_WEEK [total travelled distance per week]	x	–	–
ENV_FR_MOB [air quality and CO_2 emissions impact in decisions about mobility]	–	x	x
SCORE_TRANS_SYS [supporting government actions affecting the transport system]	–	x	x
SEV_TRAF_PROB [severity of traffic problems]	–	–	x
BILL_INFORM_MOD [issues related to billing and the provided information about modernisation]	–	x	x
FIN_CONS_MOD_HIND [financing the refurbishment and further hindrances of carrying out the modernisation]	–	x	x
COOL_HEAT_HAB_INF [cooling and/or heating habits plus their influencers]	–	x	x
LESS_ENERGY_CONS [less energy consumption: mobility and household appliances]	x	–	–
AGR_INCONV_EFM [accepting the inconvenience arising from environmentally friendly measures]	x	x	–

RQ2: Which socio-economic phenomena prevail in Hungary regarding environmentally conscious consumer behaviour?

Table 8 contrasts the mean of the cluster with outstanding environmental awareness with that of their counterparts in analogy with Table 6. Each asymptotic independent samples z-test relies on the descriptive statistics of the most conscious customer group (Cluster 1) and the closest mean of the corresponding remaining cluster (Cluster 2 or 3). The latter figures are marked with cursive font type.

Table 8. Mean and standard deviation of the variables for each cluster (k=3), significance level of the asymptotic independent samples z tests, 477 cases, only Hungary (missing cases excluded listwise)

Variable [description]	Cl. 1 Mean	Cl. 2 Mean	Cl. 3 Mean	Cl. 1 Std. dev.	Cl. 2 Std. dev.	Cl. 3 Std. dev.	z-test	p-value
S1 [number of persons in the household]	2.68	2.25	*2.41*	1.17	1.16	1.21	2.04	0.021
S2 [highest level of studies]	3.15	2.81	*2.85*	0.55	0.72	0.64	4.57	0.000
S3 [current employment status]	1.51	2.54	*2.19*	1.23	1.61	1.63	-4.25	0.000
S4 [year of birth]	1970.15	1963.19	*1966.45*	11.63	14.74	14.61	2.53	0.006
S5 [gender]	1.59	1.56	*1.61*	0.49	0.50	0.49	-0.32	0.374
S6 [type of area]	2.36	*3.15*	3.29	1.23	0.91	0.76	-6.67	0.000
S8 [financial status]	2.12	2.57	*2.57*	0.57	0.68	0.62	-6.82	0.000
Number of cases	190	137	150					

At a significance level of 5%, the null hypothesis can be declined for each variable except for S5. The total number of persons living in the household for at least 6 months of the year is the highest in the case of the most environmentally aware customers. They demonstrate the most favourable educational level: 92.63% of the cluster (176 persons) completed at least secondary or post-secondary non-tertiary education. As economically the most active and youngest group, 84.74% of the members (161 persons) are employed full-time. With 149 respondents (78.42%), this cluster has the largest share of urban citizens. Their overall financial status is the most advantageous: only 30 individuals (15.79%) find it difficult on present income. Interestingly, the distribution of the genders is independent of the clusters: the share of women is almost 60% in each cluster. A salient share of pensioners and rural inhabitants (both 40.15%), plus their income category

explain the environmentally friendly position of Cluster 2 in mobility; consequently, these circumstances cannot be traced back to environmental awareness (see Table 9). (*ENABLE.EU team 2019, pp. 25-26*) Not counting the type of area of residence, Cluster 1 demonstrates nearly the lowest dissimilarities: it incorporates the youngest, the most educated, and economically active urban customers with family and stable financial background. Tables 7 and 9 provide orientation when deciding on the details of actions.

Table 9. Distribution of the clusters based on social and economic characteristics, only Hungary (k=3) (*ENABLE.EU team 2019, pp. 25-26*)[30]

Variables [denomination], available answers	Cluster 1	Cluster 2	Cluster 3
S1 [total number of persons in the household]			
1	12.6%	25.5%	19.3%
2	38.4%	46.0%	45.3%
3	25.8%	13.1%	20.0%
4	17.4%	10.9%	8.7%
5-8	5.8%	4.4%	6.7%
S2 [highest level of studies]			
At the most primary education	7.4%	31.4%	24.0%
Secondary and post-secondary non-tertiary education	69.5%	53.3%	65.3%
Tertiary education (bachelor, master, PhD)	23.2%	15.3%	10.7%
S3 [current employment status]			
Employed full-time or part-time	84.7%	52.6%	64.0%
Without employment for more than 3 months	0.5%	2.2%	1.3%
Retired/pensioner	12.1%	40.1%	29.3%
Other economically inactive persons (incl. students)	2.6%	5.1%	5.3%
S6 [type of area of residence]			
A city with more than 0.5 million people: in its centre	41.6%	10.2%	4.7%
A city with more than 0.5 million people: outside its centre	2.1%	4.4%	4.7%
A town or a city with less than 0.5 million people	34.7%	45.3%	48.0%
A village	21.6%	40.1%	42.7%
S8 [financial status]			
Living comfortably on present income	7.4%	2.9%	0.7%
Coping on present income	76.8%	45.3%	48.0%
Finding it difficult on present income	12.1%	43.8%	45.3%
Finding it very difficult on present income	3.7%	8.0%	6.0%

6.7. Discussion

RQ1: The asymptotic independent samples z-tests were repeated by applying the results of the 4-means cluster analysis. Table 10 aligns the significance level (p-value) for each variable. The legend remains unaltered: a value denoted with bold font type in the column of Cluster 1 refers to the best attitude. Italic font type symbolizes the corresponding best or second-best values of the less conscious clusters.

[30] The indicated percentages are correct. The alteration from a total of 100% is due to rounding in the decimal place.

Table 10. Mean and standard deviation of the variables for each cluster (k=4), significance level of the asymptotic independent samples z-tests, 480 cases, only Hungary (missing cases excluded listwise)

Variable (better value)	Cl. 1 Mean	Cl. 2 Mean	Cl. 3 Mean	Cl. 4 Mean	Cl. 1 Std. dev.	Cl. 2 Std. dev.	Cl. 3 Std. dev.	Cl. 4 Std. dev.	z-test	p-value
H12B (lower)	**2.40**	3.18	*2.76*	2.99	1.17	1.52	1.39	1.48	-2.23	0.013
AGR_NEG_STAT (lower)	**10.18**	11.19	*10.81*	11.11	2.22	2.52	2.20	2.21	-2.21	0.014
TIME_SHARE_ PREF_MODE (higher)	48.80%	*65.19%*	55.49%	52.66%	0.41	0.44	0.43	0.46	-2.76	0.003
TOT_DIST_PER_ WEEK (lower)	276.22	127.52	175.45	*122.12*	221.15	154.24	195.97	134.62	6.04	0.000
ENV_FR_MOB (higher)	**8.66**	6.90	*7.24*	6.61	1.67	2.41	2.22	2.22	5.84	0.000
SCORE_TRANS_ SYS (higher)	**22.80**	*21.65*	21.16	20.33	3.87	5.13	4.45	4.10	1.82	0.035
SEV_TRAF_ PROB (higher)	**17.36**	*17.00*	16.31	15.55	3.92	4.32	4.03	4.85	0.63	0.264
BILL_INFORM_ MOD (lower)	**22.83**	33.00	30.61	*25.83*	3.86	4.26	3.37	3.15	-6.17	0.000
FIN_CONS_MOD _HIND (lower)	**24.40**	41.01	*30.14*	33.87	3.37	4.24	4.23	3.85	-12.06	0.000
COOL_HEAT_ HAB_INF (lower)	**23.91**	32.70	*25.01*	33.98	3.18	4.56	3.32	3.61	-2.67	0.004
LESS_ENERGY_ CONS (higher)	0.62	0.62	0.71	*0.74*	0.75	0.54	0.70	0.71	-1.25	0.106
AGR_INCONV_ EFM (lower)	9.71	*9.56*	9.88	9.57	1.95	1.81	2.16	1.85	0.55	0.291
Number of cases	99	105	160	116						

Halving the group of the most environmentally aware customers results at a significance level of 5% in a significant outperformance in the variables H12B, AGR_NEG_STAT, ENV_FR_MOB, SCORE_TRANS_SYS, BILL_INFORM_MOD, FIN_CONS_MOD_HIND, and COOL_HEAT_HAB_INF. With regard to SEV_TRAF_PROB, no significant difference can be stated at a significance level of 10% in spite of the best value achieved by Cluster 1. Although this cluster underperforms in the dimensions LESS_ENERGY_CONS and AGR_INCONV_EFM, the null hypotheses cannot be declined at a significance level of 10%. Finally, catch-up is required in mobility (TIME_SHARE_PREF_MODE and TOT_DIST_PER_WEEK). These results overwhelmingly coincide with those of Table 6, including the refusal of general best performance in each field of environmental awareness. The comparison of the means of the clusters of both runs renders it possible to identify three phenomena. First, the more environmentally aware a customer is, the more favourable values can be achieved except for TIME_SHARE_PREF_MODE and TOT_DIST_PER_WEEK. Oddly, the more environmentally aware customers travel more and attribute less importance to opting for preferred travel modes. Second, the best cluster of run k=4 (in the case of 12 involved variables: 99 customers) is a subset of the best cluster of run k=3 (191 customers). By restricting the investigation to the three initial variables, Table 11 reinforces the former statement about the relation between the two best clusters at the national level as well; however, being a subset of a larger group does not imply a stricter requirement (see the two exceptions). This sheds light on the relativity and difficulty of determining the criteria for being qualified as environmentally aware.

Table 11. Means of the variables in the case of Cluster 1 split by country, 760 cases, 3 countries

Name of the variables	k=4			k=3		
	Hungary	Spain	Ukraine	Hungary	Spain	Ukraine
BILL_INFORM_MOD	22.65	20.28	19.68	25.76	21.27	22.67
FIN_CONS_MOD_HIND	24.32	26.88	23.73	26.15	27.23	25.48
COOL_HEAT_HAB_INF	23.94	**26.08**	**25.32**	24.05	25.83	25.15
Number of cases	116	25	22	223	30	33

Third, none of the clusters of the run k=4 can be assigned to Cluster 2 (showing environmentally friendly mobility but heterogeneous in the remaining fields) of Table 6 (k=3); however, 52.90% of its members can be found in Cluster 2 of Table 10 (k=4). As a consequence, not only the total number of clusters but also building clusters from less

environmentally aware customers are malleable. These results partly modify the combinations of proposed actions and affected clusters highlighted in Table 7, e.g. no cluster-specific action is required for LESS_ENERGY_CONS and AGR_INCONV_EFM.

RQ2: The socio-economic differences are reflected in Table 12 by applying k=4. Each asymptotic independent samples z-test makes use, on the one hand, of the means and the variances of the most conscious customer group and, on the other hand, of those of the remaining cluster with the closest mean (marked with cursive font type).

Table 12. Mean and standard deviation of the variables for each cluster (k=4), significance level of the asymptotic independent samples z-tests, 477 cases, only Hungary (missing cases excluded listwise)

Variable [description]	Cl. 1 Mean	Cl. 2 Mean	Cl. 3 Mean	Cl. 4 Mean	Cl. 1 Std. dev.	Cl. 2 Std. dev.	Cl. 3 Std. dev.	Cl. 4 Std. dev.	z-test	p-value
S1 [number of persons]	2.72	2.19	2.48	*2.50*	1.25	1.12	1.10	1.27	1.32	0.093
S2 [level of studies]	3.23	2.78	*2.98*	2.87	0.51	0.71	0.60	0.68	3.68	0.000
S3 [employment status]	1.23	2.45	*2.02*	2.29	0.87	1.63	1.52	1.69	-5.27	0.000
S4 [year of birth]	1971.04	1963.14	1966.52	*1967.66*	10.67	14.23	13.30	15.55	1.87	0.031
S5 [gender]	1.58	1.57	*1.57*	1.63	0.50	0.50	0.50	0.48	0.20	0.420
S6 [type of area]	2.18	3.21	*2.83*	3.24	1.23	0.87	1.11	0.81	-4.26	0.000
S8 [financial status]	2.02	2.59	*2.36*	2.57	0.48	0.58	0.71	0.64	-4.54	0.000
Number of cases	98	104	160	115						

At a significance level of 10%, the null hypothesis can be declined for each variable except for S5, which is identical to the previous results (see Table 8). Cluster 1 produced more advantageous means thanks to a shift towards larger households and higher educational levels, more full-time employment, younger members, more accentuated prevailing of urbanisation, and more favourable financial background. The distribution of women and men remained at approximately 60%:40% in each cluster. Cluster 2 demonstrates merely slight alterations compared to the group of the same index in Table 8 that confirms that primarily economic inactivity, higher age, the considerable share of rural inhabitants, and coping with financial difficulties entail the seemingly eminent position concerning mobility. (*ENABLE.EU team 2019, pp. 25-26*)

The findings are in accordance with the results of other authors. Table 13 establishes a connection between the results of this analysis and the statements of cited articles by relying on Tables 2 and 7.

Table 13. Reflecting on the statements from the literature review

Name of the author(s)	Statement(s) of the cited author(s)	Appearance in this study
Barbarossa–Pastore	Higher perceived prices and improper communication as impediments	Confirmation: AGR_INCONV_EFM and BILL_INFORM_MOD, both needing improvement
Raletić Jotanović et al.	1. Differences in pro-environmental consumer behaviour amongst nations 2. Role of demographic and socio-economic characteristics (e.g. educational level, monthly income)	1. Confirmation: Table 11 2. Confirmation: Tables 8 and 12
Zalega	Factors resulting in sustainable consumption patterns: gender, age, educational background, monthly disposable income, place of residence, and attending courses of the University of the Third Age	Regardless of gender and attending courses confirmation: Tables 8 and 12
Craig	Clients being aware of energy efficiency programmes realise reductions in both consumption and emissions.	From a broader perspective confirmation as the correlation between FIN_CONS_MOD_HIND and COOL_HEAT_HAB_INF is +49.70%.
Werner	Lack of susceptibility to carbon dioxide emission reductions	Confirmation in governance, refutation in mobility, the means of the variables [best value]: M5H as part of ENV_FR_MOB: 3.91 [5] M8D as part of SCORE_TRANS_SYS: 3.42 [5] M9F as part of SEV_TRAF_PROB: 4.23 [5] LESS_ENERGY_CONS: 0.68 [3] G5B and G5D as part of AGR_INCONV_EFM: 2.78 [5] and 4.59 [1]
Ge et al.	Role of initial cost and allowance in the spread of solar heating and cooling systems	Confirmation: FIN_CONS_MOD_HIND, needing improvement
Chen et al.	Role of the cost of devices and the price of grid electricity, emphasising realisable energy savings and economic benefits	BILL_INFORM_MOD, G5B and G5D as part of AGR_INCONV_EFM, each of them needing improvement
Eon et al.	Role of technology, practices, knowledge, and behaviour in heating and cooling	BILL_INFORM_MOD, FIN_CONS_MOD_HIND, COOL_HEAT_HAB_INF, each of them needing improvement

RQ1: The findings elucidated that none of the clusters can be considered as a paragon. Even the most environmentally aware customers demonstrate less conscious attitudes in several aspects of mobility and governance. Evaluating the declared attitudes of customers by means of cluster analyses and asymptotic independent samples z-tests identified the territories to be dealt with.

RQ2: In view of socio-economic attributes, the group of the most environmentally aware customers is the most homogeneous as it embodies the most educated, economically active urban citizens with family and stable financial background.

6.8. Conclusion, limitations, and further research

RQ1: This study attempted to describe the type of customer appertaining to various levels of environmental awareness by virtue of selected fields of the sections on home, mobility, heating and cooling, plus governance. Subsequently, the directions of increasing consciousness were designated in a tailored manner with respect to the level of environmental awareness. In addition, the scrutiny disclosed concomitant phenomena. The more environmentally aware a customer is, the more favourable values can be achieved except for the share of preferred travel mode and the total travelled distance. Decision-makers must face the inherent relativity and difficulty of narrowly determining the criteria for being qualified as environmentally aware. Not only the total number of different levels of awareness but also building clusters from less environmentally aware customers are malleable.

RQ2: Social and economic characteristics play a crucial role in shaping the choices of customers towards environmentally conscious consumption. The group of the most environmentally aware customers can be identified by reason of their qualities emerging in higher educational level and monthly income, economically active employment status, living in urban areas in a household with on average 2.7 members. Less conscious groups are more heterogeneous by demonstrating significant deviations from the best performers.

Limitations and future research:

The results have some limitations. First, one of the limitations is engendered by the missing values represented by the ‘Do not know’ or ‘Did not answer/No answer/Refuse to answer’ or ‘Not applicable’ records in the dataset. The greater the number of involved variables is, the more this general deficiency prevails. Table 14 outlines the impacts of missing values resulting in decreasing datasets and restricted circles of countries suitable

for analysis. Ignoring missing values for the sake of a larger dataset is not recommended, as it would render particular attitudes incomparable plus would lead to incorrect conclusions, e.g. empty cells would produce many favourable low values in the case of the variables of heating and cooling, which is not due to environmental awareness. Likewise, the opposite direction remains problematic, as achieving a smaller value cannot be traced back to conscious value declarations arising from a low level of environmental awareness. Hence, by dealing with the trade-off between larger datasets and the quality of results, the latter was given priority in this article.

Table 14. Number of records split by countries

Country	All records irrespective of missing values	Number of full records		
		3 variables (Heating and cooling)	+9 extra variables (Home, Mobility, Governance)	+7 socio-economic variables
Hungary	1,022	569	480	477
Spain	760	102	0	0
Ukraine	1,011	89	0	0
Total	2,793	760	480	477

Second, Table 1 foreshadowed a limitation with respect to the sections. Only a subset of countries proved to be appropriate in merit for analysis despite the 11 ones in the ENABLE.EU database. By applying a balanced initial point in light of the trade-off between involving more states and assessing more topics, the final results rest solely on Hungarian data.

Future research may provide more profound insights into single sections and reveal the interrelatedness between the sections on prosumer and electricity.

Seeking for a remedy for global problems begins with educating and mobilising customers so that they act in an environmentally conscious way. Although the hypothesis of the simultaneous presence of best-practice routines could not be buttressed, a general approach may prove to be the most effective instrument when raising the awareness of less conscious groups of the population to bolster improvements and hence greening a larger slice of the economy.

Reducing resource consumption (including energy use) in the areas of housing and mobility habits and transforming households into prosumers are globally viable means coupled with a high standard of living. These cover shifting towards local vegan /plant-based/ nutritional habits, applying energy efficiency and relying on renewable energy

sources in dwellings, collecting waste selectively, making use of public transport or private electric vehicles, prolonging the effective lifespan of products, seeking for repairs and further services with a low environmental load. In addition, environmental awareness will advantageously impact the assessment of and identification with national policies.

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7. International comparative analysis of prosumers in selected fields of energy use and further customer preferences in environmental issues

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Abstract

By providing insights into the energy choices and attitudes of retail customers, this article widens the knowledge about consumer behaviour related to photovoltaic (PV) systems. The calculations rely on the dataset of a survey conducted in Italy, Norway, Serbia, Ukraine, and the United Kingdom between 2016 and 2019 by ENABLE.EU team. (1) The analysis revealed the areas where both prosumers and traditional customers with PV plans in the near future demonstrate significant advancements. These common characteristics are the type of building, use of energy-efficient bulbs, having smart meters, less energy consumption, acceptance of the inconvenience arising from eco-friendly measures, educational level, and household income. Further differentiating attributes leading to PV plans are family size, employment status, age, gender, and commitment to environmental issues. In addition, prevailing phenomena were identified between Western and Eastern countries. (2) Prior to PV installations, formal information channels (one-sided p-value: 6.01%) are preferred when obtaining information about such systems. Both in the circle of prosumers and those with PV plans in the near future, technological, environmental, and remaining (e.g. financial) reasons are the most motivating drivers ranked in ascending order. (3) Ultimately, the study examined the nexus amongst having future PV plans, the routines for own energy conservation actions, and the evaluation of factors detaining other people from saving electricity.

Keywords: environmentally conscious consumer behaviour, sustainable consumption, prosumers with a photovoltaic system

7.1. Introduction

On the 25th of September 2015, the General Assembly of the United Nations adopted in New York 17 Sustainable Development Goals (SDGs) to be achieved by 2030. By redefining the embeddedness of the economy into nature and society, the SDGs offer a comprehensive framework. Combatting climate change (13th) necessitates, amongst others, the accomplishment of many SDGs, such as ending poverty (1st), providing access to affordable and clean energy (7th), fostering innovation and sustainable industrialisation (9th), creating sustainable and resilient cities and communities (11th), and spreading sustainable consumption and production patterns (12th). (*United Nations, 2015, pp. 1, 14*) Decarbonisation targets lessening or removing greenhouse gases responsible for anthropogenic (i.e. originating in human activity) climate change and concomitant corollaries, e.g. sea level rise and increase in mean temperature. Instead of tackling them, preventive mitigation should be given priority. In this manner, the augmentation in global average temperature in the 21st century can be limited not only to the jointly accepted 2°C but to 1.5°C relative to pre-industrial levels in accordance with the Paris Agreement. It is a legally binding international treaty in force after its ratification in 2016. (*United Nations, 2023*) Focus points are the energy and mobility turn whose estimated potential is an 80 to 90% reduction in carbon dioxide emissions. (*Bild der Wissenschaft, 2019, p. 9*) For the current decade, the European Union envisages cutting back greenhouse gas emissions by at least 55% by 2030 compared to 1990. The European Green Deal designates 2050 as the target year for achieving complete carbon neutrality. (*European Commission, 2021*)

As a consequence of aggravating global perils, countries should be urgently impelled to realise steeper slopes in the reduction of greenhouse gases, which enable them to remain within the ecological threshold. First, the main ongoing instruments are composed of increasing energy savings and efficiency. Second, preserving and extending the prominent role of carbon-neutral energy, thereby augmenting the share of renewable energy, and utilising the waning reserve of fossil resources in a more eco-friendly manner can be highlighted regarding power supply. Third, modernising district heating systems, enhancing storage capacity, developing new supply routes, attracting investments into energy-sensitive sectors, constructing cross-border capacities, integrating the grid network at the international level, and further regional cooperation are also parts of this concept. (*Hübner, 2019, pp. 185-207*)

Building more on non-depletable sources (e.g. solar, wind, and geothermal) and establishing the base of the hydrogen economy (mobility, power generation, storage technology, and feedstock) can result in a more decentralised power supply meeting the criteria of affordability, sustainability, and uninterrupted availability. (*World Economic Forum, 2023*) Following the principle of biomimicry in the context of decentralisation, retail prosumers can play a role similar to mitochondria in cellular local energy production. Etymologically, a prosumer unifies the energy producer and the consumer into one single individual. Prosumers are 'small-scale end users who, in addition to using electricity from the grid, generate power for their own use and export back into the electricity system'. (*Inderberg et al., 2018, p. 258*) Their penetration contributes not only to environmental sustainability and decarbonisation but also to energy democracy and energy justice. (*Wittmayer et al., 2022, pp. 1-2*) Regarding the energy mix of primary energy consumption in 2021, the share of fossil fuels was globally close to 82.28%: oil amounted to 30.95%, natural gas to 24.42%, and coal to 26.90%. The proportion of nuclear energy is 4.25% and the remaining 13.47% belongs to renewables. Paragons (such as Norway and Sweden) already have a carbon-neutral share (nuclear energy, hydroelectricity, solar, wind, biofuels, geothermal, biomass, and other carbon-neutral sources) surmounting 70%. Despite the almost exponential expansion of solar energy since its introduction in the 1980s, its potential still offers abundant benefits by creating more prosumers (both residential and corporate) and moderating the vulnerability of the energy supply. (*BP, 2022*) In addition to carbon dioxide, the energy industry is responsible for a considerable share of the emissions of air pollutants such as acidifying gases (nitrogen oxides and sulphur oxides). (*HCSO, 2023*)

This research aims at revealing relationships contributing to economic conjuncture, societal prosperity, and environmental health by evaluating the current position and attitudes of retail prosumers and their counterparts with or without PV plans in the near future. The household survey conducted by ENABLE.EU team provided comprehensive international data in the fields of home, mobility, prosumers, heating and cooling, electricity, governance, and socio-economic characteristics. To address the research questions (RQs), asymptotic independent samples z-tests, chi-square tests of independence, and logistic regression were applied. First, indicators of environmental awareness and social and economic attributes were investigated to determine whether they can be qualified as differentiators in the context between prosumers and traditional customers and between traditional customers with PV plans in the near future and those

without such intentions. Ultimately, this scrutiny was expanded from the level of individuals to that of nations. (RQ1) Second, conclusions were drawn with regard to the role of information channels and the type of triggering reasons prior to the installation of PV systems or resulting in PV plans. (RQ2) Third, the nature of interrelationships amongst having future PV plans, the routines for own energy conservation actions, and the evaluation of factors detaining other people from saving electricity was disclosed. (RQ3) Furnishing stakeholders with valuable findings may improve the environmental awareness of individuals (through targeted communication about energy savings, energy efficiency, renewables, and recent progress). Furthermore, generating appropriate market incentives related to installation, emphasising decisive reasons (e.g. financial benefits during use spanning more decades), opting for the most efficient information channels, and eliminating hindrances can support the spread of cleaner technologies and, as a consequence, bolster the transition towards carbon neutrality and advance its date.

7.2. Literature review

By relying on all databases offered by the Web of Science, the term ‘prosumers’ as the sole keyword was used to ensure as many hits as possible without any restrictions. The simplified systematic review encompassed 618 open-access articles about prosumers in the field of renewable energy production irrespective of the publication year. The bibliographic analysis based on the title, the name of the journal, and the abstract resulted in 25 papers that could be considered related to the decision-making process prior to becoming a prosumer or having PV plans in the near future. Most articles address promoting prosuming. Categorising the remaining hits was out of the scope of the review.

Zdonek et al. (2022, pp. 19-20) assessed a program initiated by the Polish government targeting the popularisation of PV microinstallations with the purpose of future expansion. Motivators, barriers, concerns perceived by beneficiaries, experiences gained during the initial period with regard to the stability of the electricity network, operational risks, and expectations related to the future disposal after the useful lifetime of PV panels were surveyed. *Guzman–Henao* (2022, pp. 11-12) applied the game theory to point to improvement emerging from the interaction between prosumers and consumers at the residential level in Colombia. Both eliminating the income tax coupled with sold electricity surpluses and selling surplus amongst consumers would have a salutary effect. *Xia-Bauer et al.* (2022, p. 14) initiated new prosumer-oriented business

models in Germany, namely, peer-to-peer electricity trading and the aggregation of small-size prosumers. The authors collected drivers and barriers related to both business model innovations and ascribed a particular role to utilities when upscaling the participation of prosumers. *Kettner et al.* (2022, p. 629) made recommendations for a more equitable future electricity system in Austria characterised by more inclusion through superseding current legal barriers, relying on renewable energy communities and targeted support in the function of the household's income. *Inderberg et al.* (2018, pp. 267-268) identified national prosumer pathways by contrasting Germany, Norway, and the United Kingdom. The respective developmental trajectories are shaped by both country-specific factors and overlapping dimensions. *Karjalainen–Ahvenniemi* (2019, p. 51) highlighted the importance of trustworthy information and professional advice by scrutinising the adoption of residential PV systems in Finland. *Kotilainen–Saari* (2018, pp. 17-18) evaluated policies as influencers in shaping customers' attitudes. The researchers recommend discernment with respect to the target group (non-adopters of PV systems or prosumers) and the nature (economic or non-economic, by underlining the impacts of the latter) of policies. By investigating the domestication process of PV technology in Norway and the United Kingdom, *Standal et al.* (2020, p. 8) suggested considering gender and social aspects and practical knowledge when designing policies. *Zimmermannová et al.* (2018, pp. 14-15) examined the impact of subsidies on financial indicators (such as NPV and IRR) of retail photovoltaic projects in the Czech Republic. Subsidies lessen the initial investment costs; hence, they make the payback period shorter and the project more lucrative. Many further authors analysed the profitability of PV-related investments (installation and optionally electrical energy storage) (*Gissey et al., 2021; Niekurzak–Kubińska-Jabcoń, 2021; Szelag-Sikora et al., 2021*). Both *Olczak et al.* (2021, p. 13) and – to a smaller extent – *Niekurzak–Kubińska-Jabcoń* (2021, p. 10) estimated avoidable greenhouse gas emissions by increasing PV capacities. The profile of PV end users was explored in Poland by *Ropuszynska-Surma–Weglarz* (2018) and in Denmark with chronological distinction by *Hansen et al.* (2022). Inventorying enablers (and optionally disablers) contributing to the diffusion of prosumer PV systems is one of the most favourite research fields (*Palm, 2018; Panos–Margelou, 2020; Rataj et al., 2021; Rausch–Suchanek, 2021; Mularczyk et al., 2022; Schwanitz et al., 2022; Wicki et al., 2022*). Finally, a few studies have expounded the advantages of becoming collective prosumers in energy communities compared to their private counterparts (*Petrichenko et al., 2022; Ritzel et al., 2022; Wittmayer et al., 2022*).

The dissimilarities amongst the types of customers, the antecedents of PV microinstallations, and the level of environmental awareness of individuals with PV plans are possible research gaps. Based on the literature review and the available data, three RQs were formulated. This study aims at disclosing the following:

- First, which variables do qualify as differentiators when comparing (i) prosumers with traditional customers, (ii) those having PV plans in the near future with those without such intentions, and (iii) countries with each other? (RQ1)
- Second, which conclusions can be drawn with regard to the role of information channels and that of installation reasons when making decisions about PV systems? (RQ2)
- Third, what kind of interrelationships can be identified amongst having future PV plans, the routines for own energy conservation actions, and the evaluation of factors detaining other people from saving electricity? (RQ3)

7.3. Method

Quantitative analyses were carried out.

RQ1: Asymptotic independent samples z-tests were performed to test the equality of means. Logistic regression was employed for binary classification.

RQ2: Answering this question necessitates asymptotic independent samples z-tests.

RQ3: Chi-square tests of independence and asymptotic independent samples z-tests were executed. In addition, measures of association were calculated.

Logistic regression, the tests of independence, and the measures of association were made in the statistical software IBM SPSS Statistics Version 27. The asymptotic independent samples z-tests were carried out in Microsoft Excel.

7.4. Data collection

Between 2016 and 2019, the ENABLE.EU team undertook a project with the purpose of disclosing the drivers of individual energy choices and behaviours with the participation of 11,265 retail customers from eleven countries, of which five are relevant for this study with regard to the section on prosumers (Italy – 1,025 persons, Norway – 1,221, Serbia – 1,000, Ukraine – 1,011, and the United Kingdom – 1,015). The team compiled a questionnaire for conducting a household survey so that social and cultural

influencing factors could be revealed. The survey comprises seven sections: home/building characteristics and household possessions, mobility, prosumers, heating and cooling, electricity, governance, and social and economic characteristics. The dataset contains 473, predominantly nominal and ordinal scale variables. (*ENABLE.EU team, 2019*) Table 1 recapitulates the sections split by country.

Table 1. Dataset: available combinations of sections and countries (extract)

Country (abbreviation)	Home	Mobility	Prosumers	Heating and cooling	Elec-tricity	Govern-ance	Socio-economic
Italy (IT)	x	x	x	–	–	–	x
Norway (NO)	x	x	x	–	–	x	x
Serbia (RS)	x	–	x	–	x	x	x
Ukraine (UA)	x	–	x	x	–	x	x
United Kingdom (UK)	x	–	x	–	x	x	x
Number of countries	5	2	5	1	2	4	5

RQ1: The sections on home/building characteristics and household possessions, mobility, prosumers, governance, and social and economic characteristics bear importance for addressing this question.

RQ2: The findings rest solely on the section on prosumers.

RQ3: The sections on prosumers and electricity enable us to disclose the interrelatedness between each selected pair of variables.

7.5. Data analysis

Prior to applying the mentioned techniques, data transformation was performed as detailed in Table A1 (see online Annex).

Both Kolmogorov–Smirnov and Shapiro–Wilk tests were applied to test for normal distribution. Apart from single exceptions, the null hypothesis of normal distribution can be declined. For this reason, the results of independent samples z-, t- or Welch tests are not valid. Asymptotic independent samples z-tests proved to be viable alternatives for testing the equality of means as a normal distribution is not a prerequisite. These tests require merely finite standard deviations and large (sub)samples, which are both ensured. In this study, a (sub)sample size of approximately 100 was accepted. A series of null hypotheses ($H_0: \bar{y} - \bar{x} = 0$) with the one-sided alternative hypotheses ($H_1: \bar{y} - \bar{x} > 0$) was carried out by dint of the formula of the asymptotic independent samples z-test. On

the one hand, $\bar{y}$ denotes the higher value in question, and $\bar{x}$ refers to the corresponding lower value; on the other hand, $\delta_0 = 0$. Under the square root stand variances (s^2) and sample sizes (n). (*Hunyadi et al., 2000, pp. 468-469*)

$$Z = \frac{\bar{y}-\bar{x}-\delta_0}{\sqrt{\frac{s_Y^2}{n_Y}+\frac{s_X^2}{n_X}}} \rightarrow N(0,1) \qquad /1/$$

The null hypothesis of independent variables can be tested by means of the test of independence. This chi-square test requires that each expected count (n_{ij}^*) is at least 5. By denoting the number of rows with r and that of columns with c, the test statistic can be calculated as detailed below:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(n_{ij}-n_{ij}^*\right)^2}{n_{ij}^*} \qquad /2/$$

The null hypothesis can be declined if the test statistic exceeds the right-tailed value of $\chi_{1-\alpha}^2(\nu)$, where α is the significance level and ν is the number of degrees of freedom determined as ν=(r–1)·(c–1). (*Hunyadi et al., 2000, pp. 460-462*) In addition, both symmetric and directional measures of association were calculated. (*Kovács, 2014, pp. 35-40*)

Both logistic regression and discriminant analysis are appropriate tools for classifying cases. Specifically, logistic regression was given priority due to the lower number of its prerequisites and the dichotomous nature of the dependent variable (y) with Bernoulli distribution. One of the requirements is the rule of thumb between the sample size (n) and the number of variables (p): n>10p. In addition, regressors should be linearly independent to avoid multicollinearity between them. The logit transformation of the probability (i.e. the natural logarithm of the odds ratio) is a linear function of the explanatory variables ($\underline{x}$) as shown below:

$$logit\, p(\underline{x}) = ln\left[\frac{p(\underline{x})}{1-p(\underline{x})}\right] = ln(odds) = \underline{\beta}' \cdot \underline{x} \qquad /3/$$

Based on (3), the multiple logistic regression model can be expressed as follows:

$$p(\underline{x}) = \frac{\exp(\underline{\beta}'\cdot\underline{x})}{1+\exp(\underline{\beta}'\cdot\underline{x})} \qquad /4/$$

The regression parameters ($\underline{\beta}$) are estimated with the maximum likelihood technique. (*Kovács, 2014, pp. 87, 93-95, 126-147*; *Szüle, 2016, pp. 49-58*)

7.6. Findings

RQ1: The analysis rests on three levels as detailed below.

1st level: Comparing prosumers with traditional customers (i.e. those currently not having any PV systems) along each aspect where available data are appropriate for a more profound investigation. **2nd level**: Traditional customers are differentiated according to whether they have PV installation plans in the near future. Regarding the split along PV plans in the near future, the difference between the subtotals and the total number is caused by the 'Do not know' answers. **3rd level**: Traditional customers are split by country so that national specificities can be made visible.

Type of building (H1):

1st and 2nd levels: The differences are significant. According to the mean, both prosumers and traditional customers with PV plans in the near future live in houses attached to building(s), e.g. an individual rooftop solution is possible. The type of residence in the case of those without plans shifts towards apartments, which restricts the leeway for installation.

3rd level: Based on the share of single-family houses, the international overview aligns the countries in the next descending order: 1. UK, 2. RS, NO, 3. UA, 4. IT.

Floor area (H3):

1st level: At a significance level of 5%, the hypothesis that prosumers live in dwellings with a greater floor area can be rejected.

2nd level: The floor area is not an explanatory variable of having PV plans in the near future.

3rd level: The countries demonstrate significant dissimilarities. The home of Norwegians is the most spacious, followed by IT, RS, UK, and UA.

Proportion of energy-efficient bulbs inside homes (H12B):

1st level: Prosumers reached a significantly higher proportion of energy-efficient bulbs inside homes (midway between 50% and 100%) than those without installed PV systems (slightly above 50%).

2nd level: Similarly, traditional customers with PV plans in the near future made more considerable advancements in the transition towards energy-efficient bulbs than their counterparts.

3rd level: Within-group analysis elucidated that the United Kingdom takes the lead by attaining the level of prosumers before Italy and Norway (no significant difference

between them at a significance level of 5%). Ukraine is the closest to the group average. By estimating the proportion for one-fourth, Serbia lags behind.

Having an electricity smart meter (H13A):

1st level: The share of citizens equipped with electricity smart meters is higher in the case of prosumers: 2 out of 5 respondents compared to the proportion 1:5 perceived in the circle of non-adopters of PV systems.

2nd level: Those with PV plans in the near future made advancements in the field of installing electricity smart meters compared to their counterparts.

3rd level: In Norway, more than half has electricity smart meters (salient share of hydroelectricity). (*BP, 2022*) In the United Kingdom, the ratio of users to total individuals is approximately 1:4. In the remaining countries (IT, UA, and RS), the penetration is rather rudimentary.

Having gas and heating smart meters (H13B and H13C):

The number of definite responses is inferior to the previous question. The use of natural gas in Norway is negligible.

1st and 2nd levels: A higher share of both prosumers and traditional customers with PV plans in the near future benefits from metering than that of the respective less conscious group.

3rd level: Similar phenomena prevail as identified concerning electricity smart meters. Heating smart meters (1. IT, UK, 2. UA, 3. RS) are less common than gas smart meters (1. UK, 2. IT, 3. RS, UA).

Agreeing with negative statements about environmental issues (AGR_NEG_ STAT):

1st level: No significant difference can be captured at a significance level of 10% between prosumers and their counterparts not having PV systems when assessing how they can identify themselves with environmental issues.

2nd level: Dividing the latter group into two parts along installation plans in the near future reveals a significant difference. Those with plans occupy a more favourable position with the presumed explanation that not refusing to act manifests itself in conceiving such plans.

3rd level: The comparison between countries led to significant differences for each case. By demonstrating the lowest average and thus the most moderate resistance against participation in environmental actions, Norway ranks number one. It is followed by UK, UA, RS, and IT.

Less energy consumption due to mobility and household appliances (LESS_ENERGY_CONS):

1st level: Prosumers have significantly less energy consumption thanks to environmentally friendly alternatives than citizens without any PV systems.

2nd level: Having installation plans in the near future results in significantly less energy consumption compared to the lack of such intentions.

3rd level: Country-specific dissimilarities prevail: the former members of the Western Bloc (NO, UK) significantly outpace the less developed states (UA, RS).

Agreeing with the inconvenience arising from environmentally friendly measures (AGR_INCONV_EFM):

1st and 2nd levels: Both prosumers and traditional customers with PV plans in the near future show a greater propensity for limitations in city centres for cars causing air pollution or paying higher prices for renewable energy than those without installation plans.

3rd level: Aligning countries according to how their citizens accept the inconvenience connected to environmentally friendly measures results in the order starting with the United Kingdom and Norway. The respondents from Serbia and Ukraine proved to be less supportive proponents of environmentally friendly measures if they bear disadvantages. Table 2 recapitulates the main test results.

Table 2. Asymptotic independent samples z-tests (extract, Sign.=p-value)

Variable	Mean and p-value of z-test	A) Prosumers	B) Traditional customers	Ba1) With plans in near future	Ba2) Without plans in near future
H1	Mean	1.990	2.408	2.076	2.478
	Sign.	0.000		0.000	
H3	Mean	3.365	3.151	3.121	3.165
	Sign.	0.054		0.239	
H12B	Mean	1.968	2.702	2.271	2.834
	Sign.	0.000		0.000	
H13A	Mean	1.581	1.790	1.717	1.815
	Sign.	0.000		0.000	
H13B	Mean	1.739	1.893	1.815	1.926
	Sign.	0.010		0.000	
H13C	Mean	1.723	1.959	1.922	1.971
	Sign.	0.000		0.000	
AGR_NEG_STAT	Mean	11.525	11.133	10.580	11.249
	Sign.	0.128		0.000	
LESS_ENERGY_CONS	Mean	1.429	0.851	1.113	0.791
	Sign.	0.000		0.000	
AGR_INCONV_EFM	Mean	8.891	9.588	8.895	9.755
	Sign.	0.005		0.000	

Variable	Mean and p-value of z-test	Bb1) Italy	Bb2) Norway	Bb3) Serbia	Bb4) Ukraine	Bb5) United Kingdom
H1	Mean	2.855	2.307	2.249	2.518	2.125
H3	Mean	3.640	3.872	3.025	2.385	2.683
H12B	Mean	2.227	2.308	4.036	2.898	1.986
H13A	Mean	1.882	1.456	1.981	1.952	1.726
H13B	Mean	1.897	..	1.982	1.987	1.771
H13C	Mean	1.918	..	2.000	1.981	1.930
AGR_NEG_STAT	Mean	11.829	10.092	11.645	11.174	10.930
LESS_ENERGY_CONS	Mean	..	1.158	0.554	0.615	1.021
AGR_INCONV_EFM	Mean	..	9.388	9.702	10.213	9.045

Monthly expenditures on electricity (H8A):

The amounts remained in the original currency and were not indexed because of inflation in spite of the circumstance that the survey was conducted between 2016 and 2019.

1st level: This investigation is hindered by low national subsample sizes.

2nd and 3rd levels: By accepting the limitations due to small subsamples (see Table 3), the null hypothesis of equal monthly expenditures on electricity cannot be declined at a significance level of 5%.

Table 3. Average monthly bill for electricity expressed in national currency

Country (currency)	Type	Mean	Std. dev.	Number of cases	z-test	p-value
Italy (EUR)	PV plans	122.94	80.91	32	1.278	0.101
	No plans	104.39	63.46	654		
Norway (NOK)	PV plans	2,167.45	6,257.45	89	1.522	0.064
	No plans	1,149.83	2,636.55	974		
Serbia (RSD)	PV plans	3,888.52	1,458.09	61	0.424	0.336
	No plans	3,805.82	1,735.57	919		
Ukraine (UAH)	PV plans	344.63	449.05	56	1.405	0.080
	No plans	259.13	286.33	826		
United Kingdom (GBP)	PV plans	84.95	158.61	252	1.227	0.110
	No plans	69.71	110.45	224		

Total distance per week expressed in kilometres (TOT_DIST_PER_WEEK):

1st level: Data are not available.

2nd level: The intention to install PV systems in the near future does not significantly influence the total distance travelled per week.

3rd level: Italians travel weekly a total distance of 119.5 kilometres, Norwegians, living in a larger country (IT: 302.1, NO: 323.8 thousand km^2), are significantly more mobile with an additional increment of 42.2 kilometres per week on average. (*HCSO, 2022, Table 9.1*)

Environmentally friendly mobility (ENV_FR_MOB):

1st level: Data are not available.

2nd level: Having PV plans in the near future does not differentiate non-adopters of PV systems with respect to their attitudes in this aspect of mobility.

3rd level: Interestingly, Italian customers ascribe more importance to air quality impact and CO_2 emissions impact when making mobility decisions.

Score of supporting government actions affecting the transport system (SCORE_TRANS_SYS):

1st level: Data are not available.

2nd level: Having PV plans in the near future does not have any impact on the score.

3rd level: Based on the international comparison, Italians support more intensively related government actions.

Severity of traffic problems (SEV_TRAF_PROB):

1st level: Data are not available.

2nd level: Having PV plans in the near future does not affect the estimation of the severity of traffic problems.

3rd level: Presumably, the Norwegian mentality, attitudes (e.g. being more tolerant) and favourable circumstances (a country with lower population density [16.6 vs. 197.4 person/km^2] and more forests in absolute value [12.180 vs. 9.566 million ha] coupled with fewer passenger cars per thousand inhabitants [544 vs. 670 pieces]) imply that traffic problems such as traffic congestion and noise, the excessive presence of vehicles, local air quality, and global warming are perceived as less severe. (*HCSO, 2022, Tables 9.1, 9.26-9.27*)

Table 4 contrasts the mobility indicators listed above.

Table 4. Asymptotic independent samples z-tests (extract)

Variable	Mean and p-value of z-test	A) Prosumers	B) Traditional customers	Ba1) With plans in near future	Ba2) Without plans in near future	Bb1) Italy	Bb2) Norway
TOT_DIST_PER_WEEK	Mean	..	146.133	274.245	137.761	119.467	161.703
	Sign.			0.115		0.004	
ENV_FR_MOB	Mean	..	6.680	6.664	6.628	7.539	5.964
	Sign.			0.441		0.000	
SCORE_TRANS_SYS	Mean	..	23.052	23.154	22.972	23.279	22.860
	Sign.			0.342		0.020	
SEV_TRAF_PROB	Mean	..	15.670	14.975	15.589	19.406	12.540
	Sign.			0.105		0.000	

Total number of persons living in the household for at least 6 months of the year (S1):

1st level: There is no significant difference in the size of households between prosumers and non-adopters of PV systems.

2nd level: Contrarily, having PV plans in the near future is a differentiator: those with installation intention have more family members (+0.4 on average).

3rd level: The size of the households is the largest in Serbia and then in Ukraine. As a consequence of demographic tendencies, Western countries (1. UK, NO, 2. IT) have smaller households.

Highest level of completed studies (S2):

1st level: Prosumers attained a higher level of completed studies than non-adopters of PV systems and are the closest to the value 4, i.e. the first stage of tertiary education (bachelor or master).

2nd level: Analogous to this phenomenon, traditional customers with PV plans in the near future are better educated than those without such intentions.

3rd level: The descending order of countries (1. NO, 2. UK, 3. UA, 4. RS, 5. IT) sheds light on significant differences in the share of participants in the education system, primarily in tertiary education. The low average position of both Serbia and Italy corresponds to secondary and post-secondary non-tertiary education. These findings are in accordance with the number of students per ten thousand inhabitants. (*HCSO, 2022, Table 9.8*)

Most typical current employment status (S3):

1st level: The null hypothesis of identical most typical current employment status between prosumers and non-adopters of PV systems cannot be declined, but surprisingly, the mean of the employment status of prosumers is the narrowest to the economically not active categories.

2nd level: In contrast, those with PV plans in the near future are more active than individuals without such intentions.

3rd level: The traditional customers of Serbia demonstrate the most active category, followed by shared rankings: 1. NO, UA, 2. UK, IT.

Year of birth (S4):

1st level: Prosumers were born earlier: at a significance level of 10%, the difference in the average year of birth amounting to 2.6 years can be considered significant.

2nd level: Contrary to the previous direction, traditional customers with installation plans in the near future are 5.2 years younger than those without such intentions.

3rd level: This investigation does not bear relevance.

Gender (S5):

1st level: As 1 denotes male and 2 female customers in the questionnaire, the null hypothesis of equal gender distribution cannot be rejected when differentiating clients along installed PV systems.

2nd level: More men can be found amongst the traditional customers with installation plans in the near future than in the circle of those not intending to establish any PV systems.

3rd level: This investigation does not bear relevance.

Type of area of residence (S6):

1st and 2nd levels: Irrespective of being a prosumer or having plans in the near future as a traditional customer, the type of area of residence cannot be considered as a differentiator. The means can be placed between living outside the centre of a city with more than 0,5 million inhabitants (value of 2) and residing in a town or a city with less than 0,5 million inhabitants (value of 3).

3rd level: Norway and the United Kingdom are the most urbanised countries with an outstanding share of urban population: 83.3% and 84.2% respectively. As value 4 stands for villages, the Serbian mean shifts towards rural settlements, which is confirmed by the fact that 56.7% of the total population lives in cities (UA: 69.8%, IT: 71.3%). (*World Bank, 2023a*)

Subjective evaluation of current household income (S8):

1st level: In accordance with the financial requirements of PV systems, prosumers evaluate their present income – in spite of subjectivity – more advantageous than non-adopters of PV systems. Even if the value of 2 denotes coping with financing the current standard of living, this fact does not hamper the installation.

2nd level: The same statement relates to the interrelationship between traditional customers with installation plans and those without such intentions.

3rd level: In the case of the international comparison (1. NO, 2. IT, 3. UK, 4. RS, 5. UA) of non-adopters of PV systems, the accruals in the mean hint at emerging difficulties when financing the current standard of living. The indicator of GDP per capita basically underpins the previous order of the countries: 1. NO, 2. UK, 3. IT, 4. RS, 5. UA. (*World Bank, 2023b*)

Table 5 provides an overview of socio-economic characteristics.

Table 5. Asymptotic independent samples z-tests (extract)

Variable	Mean and Sign. of z-test	A) Prosumers	B) Traditional customers	Ba1) With plans in near future	Ba2) Without plans in near future	Bb1) Italy	Bb2) Norway	Bb3) Serbia	Bb4) Ukraine	Bb5) United Kingdom
S1	Mean	2.907	2.723	3.064	2.706	2.425	2.575	3.168	2.822	2.650
	Sign.	0.187		0.000						
S2	Mean	3.696	3.296	3.500	3.263	3.016	3.613	3.070	3.297	3.433
	Sign.	0.000		0.000						
S3	Mean	2.826	2.597	2.351	2.592	2.753	2.552	2.352	2.601	2.746
	Sign.	0.108		0.001						
S4	Mean	1966.7	1969.3	1973.6	1968.4					
	Sign.	0.077		0.000						
S5	Mean	1.505	1.548	1.470	1.558					
	Sign.	0.203		0.000						
S6	Mean	2.638	2.757	2.782	2.770	2.851	2.424	3.132	2.763	2.681
	Sign.	0.166		0.410						
S8	Mean	1.957	2.288	2.192	2.314	2.095	1.821	2.382	3.034	2.175
	Sign.	0.000		0.001						

RQ2: At a significance level of 10%, prosumers prioritised formal information channels when obtaining information about PV systems. Installation with the purpose of affordable own energy and other (non-environmental and non-technological) reasons dominates, followed by environmental reasons. Technological reasons were the least frequently enumerated. Table 6 highlights the main results. The distribution of the variable P1 confirms the outstanding role of financial reasons: 64 of 97 respondents sell surplus PV electricity via the public electricity grid. Although the share of sellers deviates from country to country, the low sample sizes do not render it possible to test assumed dissimilarities.

Table 6. Asymptotic independent samples z-tests, 97 prosumers

Variable	Mean	Std. dev.	Number of cases	z-test	p-value
FORM_INF_PV_SYS (y_1)	0.74	0.57	80	(H_1: $y_1>y_2$) 1.55	0.060
INFORM_INF_PV_SYS (y_2)	0.59	0.65	80		
FIN_OTH_REASON (y_3)	1.04	0.63	84	(H_1: $y_3>y_4$) 5.47	0.000
ENV_REASON (y_4)	0.51	0.61	84	(H_1: $y_4>y_5$) 3.38	0.000
TECH_REASON (y_5)	0.23	0.47	84		

Analogous to the previous findings, the descending order of importance of installation reasons begins with affordable own energy and other (non-environmental and non-technological) motives, with a distinct difference were evaluated environmental

benefits in the circle of traditional customers with PV plans in the near future. Technological reasons as less relevant influencers close the comparison as outlined in Table 7.

Table 7. Asymptotic independent samples z-tests, 579 traditional customers with PV plans in the near future

Variable	Mean	Std. dev.	Number of cases	z-test	p-value
AGR_FIN_OTH_REASON (y_1)	8.47	1.86	559	(H_1: $y_1>y_2$) 12.41	0.000
AGR_ENV_REASON (y_2)	7.09	1.81	537	(H_1: $y_2>y_3$) 4.19	0.000
AGR_TECH_REASON (y_3)	6.57	2.22	550		

RQ3: To test the assumption that routines for own energy conservation actions influence the opinion about why others do not participate in saving electricity, cross-tabulation analysis was carried out by relying on two ordinal variables. The first variable, i.e. the number of routines for own energy conservation actions (ROUT_ENER_ CONS_ACT) encompasses checking rooms before leaving the home, switching lights off before leaving rooms, and unplugging electronic appliances after use. Hence, it ranges from 0 to 3. The higher the value is, the more environmentally conscious the customer is. These routines were considered equivalent when summing them. The second variable, the score given to estimate the factors detaining other people from saving electricity (DET_OTH_SAV_ELEC) attempts to quantify the perception of individuals regarding how they judge mainstream practices. To create an ordinal variable, the interrogated factors were assumed to be weighted identically and classified into three categories: 4-9, 10-15, and 16-20 points. The lower the score is, the better the judgement corresponds to reality as the members of the European Union achieved advancements in energy efficiency, moving towards a higher share of renewable energy, and reducing greenhouse gas emissions. (*European Commission, 2021*) Tables 8 and 9 recapitulate the observed cases via cross-tabulation. The expected count is at least 5 for each cell in both tables.

Table 8. Contingency table of Serbia

	Count	DET_OTH_SAV_ELEC (grouped)			Total
		4–9	10–15	16–20	
ROUT_ENER_CONS_ACT	0	13	117	85	215
	1	17	109	58	184
	2	43	151	81	275
	3	43	171	112	326
	Total	116	548	336	1,000

Table 9. Contingency table of the United Kingdom

	Count	DET_OTH_SAV_ELEC (grouped)			Total
		4–9	10–15	16–20	
ROUT_ENER_CONS_ACT	0	13	63	26	102
	1	19	196	80	295
	2	14	206	122	342
	3	5	155	116	276
	Total	51	620	344	1,015

In the case of assigning customers to 3 categories regarding the variable DET_OTH_SAV_ELEC, the country-specific cross-tabulation analyses confirm the dependence of the variables at the country level. The results of the chi-square tests are shown in Table 10.

Table 10. Tests of independence

Country	Test statistic	p-value
Serbia	16.121	0.013
United Kingdom	33.897	Less than 0.001

The null hypothesis of independence can be rejected at the commonly used significance levels in both cases. The strength of the association between the two ordinal variables was characterised by both symmetric and directional measures. The latter investigation rests on the assumption that the nature of the interrelationship between the two variables is one-sided: the number of own routines may impact how the behaviour of others is perceived. For this reason, the directional measure was computed by choosing the score (DET_OTH_SAV_ELEC) as the dependent variable.

At the significance level of 5%, the Serbian indicators describe a zero association between the score given to estimate the factors detaining others from saving electricity and the number of routines for own energy conservation actions. This special situation corresponds to the case where the variables are not independent but the correlation between them is close to zero.

If the significance level is set to 10%, both symmetric and directional measures underpin a non-zero association for each country. The rationale behind a negative association is that, on the one hand, the more environmentally conscious the customer is, the more routines for own energy conservation actions can be observed. On the other hand, increasing consciousness would imply better and up-to-date information about recent progress, which would result in lower scores given to estimating the circumstances

under which others refuse to save electricity. Correspondingly, Serbia demonstrates a weak negative association. Interestingly, a stronger contradictory positive association can be captured in the United Kingdom. Table 11 details the selected indicators of association.

Table 11. Ordinal by ordinal measures

Measures	Serbia		United Kingdom	
	Value	p-value	Value	p-value
Kendall's tau-b	–5.29%	0.056	+14.31%	0.000
Kendall's tau-c	–5.16%	0.056	+12.98%	0.000
Gamma	–8.14%	0.056	+23.51%	0.000
Spearman correlation	–5.94%	0.061	+15.80%	0.000
Somers' d symmetric	–5.25%	0.056	+14.10%	0.000
Somers' d directional	–4.66%	0.056	+12.06%	0.000

The survey encompassed the section on prosumers in addition to electricity in both Serbia and Albion. This enables us to explore the interrelationships between the next triad of variables: (i) planned PV installation in the near future, (ii) the number of routines for own energy conservation actions, and (iii) the opinion about why other people omit to save electricity. By ascribing more environmental awareness to customers pondering installing a PV system at their homes, three hypotheses were formulated.

Hypothesis (1): Customers with PV installation plans demonstrate a stronger negative association between the number of routines for own energy conservation actions and the score given to estimate the factors detaining others from saving electricity than their counterparts without such intentions.

Result: Country-specific scrutiny is not ensured as the requirement of at least 5 expected counts is not met. Even the merged sample of traditional customers with PV plans produces 1 cell with an expected count of less than 5 (exact value: 2.54). Dividing customers of the merged sample into two groups based on whether they are planning a PV installation in the near future elucidates that none of the null hypotheses of independence can be rejected. None of the subsamples confirms the presumed negative association between the number of routines for own energy conservation actions and the score given to others' passive behaviour concerning saving electricity.

Hypothesis (2): Customers with PV installation plans have more routines for own energy conservation actions than their counterparts without PV installation intention.

Result: At a significance level of 5%, both the test of independence and the symmetric measures suggest independence for Serbia and a weak negative association for the United Kingdom.

Hypothesis (3): Customers with PV installation plans are more able to evaluate the factors detaining other people from saving electricity with fewer scores; thus, their opinion is closer to reality.

Result: At a significance level of 5%, Serbia can be characterised by independence and Albion by a weak negative association.

Tables 12 and 13 indicate the results of the chi-square tests and concomitant indicators.

Table 12. Tests of independence

Denomination	Hypothesis (1)		Hypothesis (2)		Hypothesis (3)	
	PV plans	No plans	Serbia	UK	Serbia	UK
Number of records	394	1,244	985	653	985	653
Test statistic	7.994	9.197	0.747	18.389	2.864	8.149
Degrees of freedom	6	6	3	3	2	2
p-value	0.239	0.163	0.862	0.000	0.239	0.017

Table 13. Ordinal by ordinal measures, United Kingdom

Symmetric measures	Hypothesis (2)		Hypothesis (3)	
	Value	p-value	Value	p-value
Kendall's tau-b	–0.142	0.000	–0.109	0.004
Kendall's tau-c	–0.171	0.000	–0.110	0.004
Gamma	–0.235	0.000	–0.214	0.004
Spearman correlation	–0.154	0.000	–0.112	0.004
Somers' d symmetric	–0.140	0.000	–0.109	0.004

7.7. Discussion

RQ1: As an alternative approach, logistic regression was applied by opting for the forward stepwise method based on conditional statistics. Prior to the runs, the presence of multicollinearity was controlled based on two statistics coupled with linear regression: tolerance and its reciprocal, i.e. the variance inflation factor. Entering 13 predictors (H1, H3, H12B, H13A, AGR_NEG_STAT, AGR_INCONV_EFM, S1, S2, S3, age in 2019 /calculated as calendar year difference: 2019-S4/, S5, S6, S8) into the model resulted in diagnosing collinearity in the cases of H1 and H3. The absolute value of the Pearson correlation exceeds 0.2 in the interaction of H1 with S6 and H3; in addition, the same applies to the relation between H3 and S1, S6, and S8. For this reason, both the type of building and the floor area were removed from the model. Concerning adopters of PV systems, the total correct classification rate is approximately 97.7%; however, the partial

correct classification rate related to prosumers remains below 3%. As a consequence, this model cannot be considered apt for predicting prosumers. Regarding having PV plans in the near future in the circle of traditional customers, a similar undesirable outcome occurred. Despite the salient partial correct classification rate (i.e. specificity) related to not having PV plans, the slight true positive rate (i.e. sensitivity) denotes that this model cannot be used for prediction.

Table 14 summarises the regression parameters and significance levels of the logistic regression in a comparative way. Both runs 3 and 4 contain the restriction of excluding AGR_INCONV_EFM for the sake of a larger sample size, whereas run 4 tests the impact of eliminating the constant compared to run 3. The results partly confirm the significance of the explanatory variables arising from the asymptotic independent samples z-tests.

Table 14. Beta coefficients and significance levels of Wald tests

Variables	Prosumers		Traditional customers					
	Run 1		Run 2		Run 3		Run 4	
	beta	p-value	beta	p-value	beta	p-value	beta	p-value
S1 [household size]	0.2108	0.012	0.0814	0.034	0.1156	0.001	0.1063	0.002
S2 [education]	0.8504	0.000	0.2163	0.029	0.3178	0.000	0.2938	0.000
age_2019	0.0327	0.001	–0.0157	0.000	–0.0107	0.002	–0.0114	0.001
S5 [gender]	–	–	–0.3621	0.003	–0.4226	0.000	–0.4217	0.000
S6 [area of residence]	–	–	0.1185	0.014	0.1154	0.010	0.1096	0.013
H12B [energy efficient bulbs]	–0.3494	0.008	–0.3406	0.000	–0.2422	0.000	–0.2428	0.000
AGR_NEG_STAT	0.1178	0.029	–	–	–0.0751	0.001	–0.0784	0.000
AGR_INCONV_EFM	–	–	–0.1419	0.000	–	–	–	–
H13A [electricity smart meter]	–1.0825	0.000	–0.3599	0.010	–0.4117	0.001	–0.4223	0.000
Constant	–7.8094	0.000	1.2783	0.045	–0.2197	0.705	–	–
Number of cases	3,206		2,707		3,119		3,119	
Maximum correct classification rate, %	97.70		83.50		85.80		85.80	
Cut value or its range	0.26–0.32		0.45		0.4		0.47–0.48	

Likewise, *Ropuszynska-Surma–Weglarz* (2018, pp. 18-19) concluded – without indicating any correct classification rates – from their logit models that there are significant relationships between becoming a prosumer and many attributes as listed below (the findings of the present study are added in parentheses):

a) gender (partly confirmed in the sense that more men can be found amongst the traditional customers with PV plans than in the group without such intentions),

b) age (entirely confirmed: at a significance level of 10%, prosumers are older than non-adopters of PV systems, and traditional customers with installation plans in the near future are younger than their counterparts not having any plans),

c) total number of persons living in the household (partly confirmed: those with PV plans have on average 0.4 more family members than those without such plans),

d) type of building (entirely confirmed: significant difference in favour of prosumers and those with PV plans),

e) floor area (at a significance level of 5%, no significant difference exists),

f) type of education (entirely confirmed: significant difference in favour of prosumers and those with PV plans),

g) knowing energy tariff (incomparable with the respective questions E1 and E2 of the survey in the section on electricity),

h) sorting rubbish (it is not investigated in the survey),

i) washing or ironing at particular times (it is not investigated in the survey),

j) switching off electronic equipment just after using them (missing values in the cells E6A3 and E6A4 as part of ROUT_ENER_CONS_ACT do not enable any underpinned comparison),

k) using LEDs (entirely confirmed: prosumers reached a higher proportion of energy-efficient bulbs inside homes than non-adopters of PV systems, and the same applies to the context between traditional customers with PV plans and without plans),

l) installing energy-saving household appliances (entirely confirmed: significant difference in favour of prosumers and those with PV plans, this statement refers to both LESS_ENERGY_CONS and its part, i.e. G1A3).

Nonetheless, the co-authors stated that the variables below proved to be irrelevant when deciding about a PV installation:

a) monthly average net income (refuted: significant difference in favour of prosumers and those with PV plans),

b) monthly expenditures on electricity (confirmed: at a significance level of 5%, no significant difference exists)

c) changing the provider (refuted based on G1A4: the probability of switching in the case of prosumers: 18/97=18.56%, those with PV plans: 70/579=12.09%, those without such intentions: 34/3868=0.88%),

d) having a smart meter (refuted if it is interpreted as having electricity smart meter: significant difference in favour of prosumers and those with PV plans).

The proposal of *Standal et al.* (2020, p. 8) to involve various gender aspects when designing new policies can be confirmed merely for the preparatory phase. The share of

men is higher in the circle of customers taking an affirmative stance on PV plans in the near future than in the group without such intentions.

Rataj et al. (2021, p. 13) discerned an oppositional prosumer's profile. They described the typical target persons of retail PV systems as individuals prior to retirement, being members of households with low income and residing in rural municipalities that are situated in regions affected by unemployment. Additionally, opting for the installation is propelled by subsidies and the price level of energy bills; however, it depends neither on local insolation nor on environmental pollution.

Rausch–Suchanek (2021, pp. 7-8), *Wicki et al.* (2022, p. 13), and *Kettner et al.* (2022, p. 629) shed light on the empirical fact that the income of households is one of the major determinants of the penetration of residential PV installations. In addition, the characteristics of the dwelling qualified as influencers in the case of the last trio of researchers.

In accordance with the articles above, *Hansen et al.* (2022, p. 9) underlined the role of economic resources and technical competences of households (the latter by virtue of technically educated men) perceived on the example of early adopters in the course of the diffusion of photovoltaics. *Schwanitz et al.* (2022, pp. 22-23) mentioned both low saving rates and restrained engagement of households as barriers and educational background as one of the enablers.

RQ2: Compared to environmental and technological reasons, the present study found the preponderance of other (e.g. financial) motivators. Furthermore, formal information channels (one-sided p-value: 6.01%) are preferred when collecting information about PV systems. Without distinguishing between formal and informal information channels in detail, *Karjalainen–Ahvenniemi* (2019, p. 51) alluded to the importance of trustworthy information stemming from both prosumers and experts. In view of the recommendations of *Kotilainen–Saari* (2018, p. 18), consumers can be actuated by both economic and non-economic policies in turning them into prosumers by ascribing more potential to non-economic policies. *Palm* (2018, pp. 7-8) split Swedish prosumers into two parts. The first wave of residential PV installations (2008–2009) was driven mainly by environmental reasons. The situation changed during the second wave (2014–2016) when economic reasons predominated. In addition to environmental and economic motives, *Mularczyk et al.* (2022, pp. 8-10) identified the ease of use of technology as influencer, while social dimensions did not impact the decision about PV investment. Analogous to the present research, *Zdonek et al.* (2022, pp. 7-8) concluded

that ecological factors fell behind economic ones (e.g. minimising the electricity costs). Likewise, *Hansen et al.* (2022, p. 9) accentuated financial gains and independence from suppliers when investigating the background of early adopters' decisions. *Schwanitz et al.* (2022, p. 23) pointed out that the deficiency of or the dominated status of post-material values (incl. environmental ones) and limited governmental support work as impediments.

RQ3: Asymptotic independent samples z-tests enable us to validate the findings.

Hypothesis (2): The United Kingdom confirms that those considering installing a PV system at their home in the near future have significantly more routines for own energy conservation actions than their counterparts without such intentions. Although the Serbian subsample consisting of customers with PV installation plans cannot be considered as a large sample (only 61 individuals), the practices of Serbian customers suggest no significant differences in the number of routines.

Hypothesis (3): Albion refutes the hypothesis that those considering installing a PV system at their home in the near future are aware of recent advancements in the fields of the expansion of energy efficiency, residual use of renewable energy, and abatement of greenhouse gas emissions. British customers with PV plans overestimate others' passive attitudes, i.e. the lack of inclination to save electricity more than those without such intentions. In the case of Serbia, the difference is not significant.

The results are presented in Table 15.

Table 15. Asymptotic independent samples z-tests

Country	Type	Mean [(2) routines, (3) scores]	Std. dev.	Number of cases	z-test	p-value
Hypothesis (2)						
Serbia	PV plans	1.59	1.15	61	0.83	0.204
	No plans	1.72	1.14	924		
United Kingdom	PV plans	1.92	0.92	333	4.11	0.000
	No plans	1.62	1.00	320		
Hypothesis (3)						
Serbia	PV plans	13.54	3.70	61	0.80	0.212
	No plans	13.93	3.59	924		
United Kingdom	PV plans	14.48	2.96	333	3.02	0.001
	No plans	13.73	3.35	320		

Pothitou et al. (2016, p. 1226) pointed to a positive relationship between propensity for pro-environmental behaviour and actions to reduce energy use. Knowledge about

greenhouse gas emissions and energy savings is a major determinant of the number of activities related to reducing energy consumption. This is in line with Hypothesis (2): having PV plans in the near future entails more routines. However, seeking for any preceding research to buttress the findings of Hypotheses (1) and (3) proved to be a vain attempt.

7.8. Conclusion, limitations, and further research

RQ1: The analysis revealed conclusions in the context between prosumers and traditional customers, as well as between traditional customers with PV plans in the near future and those without such intentions. The respective more conscious group is better educated and has a more stable financial background. Its members achieved a higher proportion of energy-efficient bulbs inside their homes, which are on average single-family houses attached to building(s). These dwellings are more likely to be equipped with smart meters. They consume less energy thanks to environmentally friendly alternatives and agree more strongly with the inconvenience arising from eco-friendly measures. In addition, traditional customers with PV plans have a larger family, demonstrate a higher share of men and more commitment to environmental issues, and are younger and economically more active than their counterparts without plans. This study identified phenomena with distinctive dissimilarities between Western and Eastern states in the aspects of size and current income of the household, use of energy efficient bulbs and smart meters, less energy consumption due to mobility and household appliances, and accepting the inconvenience coupled with environmentally friendly measures. Furthermore, the comparison between Norway and Italy pointed to significant country specificities regarding the weekly total travelled distance, opting for environmentally friendly mobility, supporting government actions affecting the transport system, and estimating the severity of traffic problems.

RQ2: Prosumers prioritise formal information channels (one-sided p-value: 6.01%) when acquiring information about PV systems. Both in the circle of prosumers and those with PV plans in the near future, technological reasons are the least motivating drivers of installation, followed by environmental and finally by other (e.g. financial) motives.

RQ3: (i) Serbia demonstrates a weak negative (one-sided p-value: 6%), whereas the United Kingdom demonstrates a stronger contradictory positive association between the number of routines for own energy conservation actions and the evaluation of factors

detaining other people from saving electricity. These two variables proved to be independent when distinguishing traditional customers along having PV plans in the near future on the merged dataset of the two states. (ii) British individuals with PV plans have more routines for energy savings and overestimate others' passive attitudes more than citizens without such intentions. In Serbia, the dissimilarities are not significant.

Limitations and future research:

The results have some limitations. The first is engendered by the missing values represented by the 'Do not know' or 'Did not answer/No answer/Refuse to answer' or 'Not applicable' records in the dataset. Second, deviations from the predefined set of values could be observed sporadically. Records were excluded pairwise to mitigate these problems. Third, Table 1 foreshadowed a limitation with respect to the sections. Selecting the countries appropriate for analysing the attitudes of prosumers designated and restricted the framework of related scrutiny. In a few cases, the prerequisites of the applied methods could not be entirely met, e.g. owing to the small size of the subsample.

Future research may unveil the interrelatedness between dimensions of consumer behaviour related to the section on mobility.

Bolstering the spread of photovoltaics may strengthen the resilience and competitiveness of the economy in tandem with a thriving society (e.g. improving well-being through higher healthy life expectancy, reducing inequalities, unfolding knowledge-based society) and restoring the integrity of ecosystems by tackling both climate change and air pollution. By applying a more human- and nature-centred approach when accomplishing the SDGs, countries have the opportunity to evolve into climate champions by reducing environmental load, dedicating substantial roles to individuals, setting up a fruitful national innovation bedrock and establishing new science-based industries as general catalysts, undergoing a transformation process associated with sustainable production and consumption patterns, plus decent economic growth. Post-war history proved that a rapid catch-up to the most developed countries and taking the lead afterwards is realisable by allocating and utilising resources purposefully and relying on the innovation regime as propelling mainspring hauling the whole institutional setting. Prosumerism is an illustrative example of how new flagships can be introduced by recognising the potential of alternative energy sources, integrating the industry of green technologies into the innovation regime, and harvesting an abundance of gains. (*Hübner, 2019, p. 207*)

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8. Common practices and dissimilarities in greening residential routine mobility in selected countries of Europe, based on a comparative analysis

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Abstract

This article aims at widening the knowledge about green mobility choices related consumer behaviour and attitudes of retail customers. The calculations rely on the dataset of a survey conducted in Hungary, Italy, Norway, Poland, and Spain between 2016 and 2019 by the ENABLE.EU team. The analysis revealed the potential enablers and disablers of environmentally friendly mobility by utilising linear regression, binary logistic regression, probit analysis, and multilayer perceptron networks on 39 predictors. Policymakers can improve the position of preferred travel modes by (i) disadvantaging traditional four-wheel vehicles, (ii) bolstering the spread of electric four-wheel vehicles, (iii) educating individuals regarding CO_2 emissions and their impacts, (iv) launching easy-to-popularise government actions affecting the transport system, (v) developing the infrastructure and accentuating the progress made, and targeting both (vi) economically active and (vii) rural citizens. Depending on the countries, supplementary areas are proposed for acting on. The scrutiny sheds light on country specificities (e.g. systemic dissimilarities, the advanced position of Norway on the electromobility pathway) and presumed paradoxes that must be addressed.

Keywords: green and smart mobility, electromobility, environmentally friendly mobility, sustainable mobility, mobility turn

8.1. Introduction

Infrastructure (e.g. public roads, railways, and other fixed track networks, the electric charging network and hydrogen refuelling stations, the entire digital ecosystem, and pipelines in energy supply) is one of the main pillars of thriving economies and is analogous to the vascular, lymphatic, and nervous systems in a healthy human body. As a consequence of prevailing globalisation and concomitant technological development in the previous decades, distances have shrunk, even the farthest corners of Earth are within

accessible reach in the 21st century. Not only products, services, workforce, and capital but also individuals, in general, have become more mobile. The progress made in the utilisation of more environmentally friendly vehicles has not counterbalanced the greenhouse gas (GHG) emissions stemming from the enhanced demand for transport in the European Union (EU). Although the COVID-19 pandemic caused a rupture in the steadily growing trend of GHG emissions due to transport perceived between 2013 and 2019 due to elevated passenger and inland freight transport, the increase in GHG emissions is likely to recrudesce in the coming years. Even with 'additional measures' (e.g. the penetration of public transport and electric vehicles and prioritisation of low-carbon fuels), sectoral GHG emissions in 2030 would hardly remain below their 1990 levels. In the next decades on EU level, GHG emissions arising from road transport are expected to fall, and those related to railway transport are likely to decrease, while the remaining emissions connected to other transport modes (both domestic and international aviation, maritime, and inland navigation) are projected to increase continuously *(EEA, 2023)*. The 11th Sustainable Development Goal aims to create sustainable and resilient cities and communities by 2030. Its target 11.2 envisages safe transport systems with general access by putting more emphasis on public transport. By making use of preventive mitigation (inter alia in the field of transport), the augmentation in global average temperature in the 21st century can be limited not only to the jointly accepted 2°C but also to 1.5°C relative to pre-industrial levels in accordance with the Paris Agreement (*United Nations, 2015, pp. 1, 14, 21; 2023*).

The European Climate Law – as part of the European Green Deal – stipulated at least 55% net reduction in total GHG emissions by 2030 compared to 1990 and set 2050 as the target year for obtaining carbon neutrality. The focus points are the energy and mobility turns. The transport-related aim is a 90% reduction in GHG emissions by 2050 compared to the base year of 1990. In 2019, the EU-28 was responsible for 7.3% of global GHG emissions; hence, its GHG emissions per capita exceeded the global average. In the territory of the EU, the share of transport was approximately 30% of total CO_2 emissions, of which 71.7% could be attributed to road transport, the majority being produced by passenger cars: cars and vans caused 12% and 2.5% of total CO_2 emissions respectively. By 2035, only carbon-neutral cars will be allowed in the EU when purchasing a new car. In line with the efforts to attain carbon neutrality, the EU decided to apply a sequence of measures (with stages in 2020, 2025, and 2030) leading to the penetration of zero- and low-emission vehicles. Correspondingly, imposing a series of performance standards on

new passenger cars by setting EU fleet-wide CO_2 emission targets (i.e. absolute limitations expressed in CO_2/km) and introducing an incentive mechanism constitute the core of the regulation *(EC, 2023; EP, 2023a-2023c; World Bank, 2023)*. By assuming the energy intensity (MJ/passenger km) and GHG intensity (g CO_2-equivalent/passenger km) of passenger transport modes, valid for 2019, the indicators of public transport (rail, buses) and two-/three-wheelers argue for reducing the use of both cars with fossil fuel combustion and aviation if reasonable parallel availability is ensured (*IEA, 2022a-2022b*).

In Hungary, the share of transport in final energy use showed a slight deviation from 27% between 2018 and 2020. Renewable energy sources in transport accounted for a low 11.6% share in the total energy use of 2020. Despite noteworthy modernisation of vehicles (e.g. spectacular growth in the number of railcars, see the self-propelled railway vehicles of Stadler) and infrastructure (e.g. electrification of the railway network, prolongation of the road network in favour of the expressway network, and prioritising asphalt and bitumen pavement), the number of passengers carried and passenger kilometres in public transport remained in 2021 below the 2015 levels due to the COVID-19 pandemic. Based on passenger kilometres, in 2019 (before COVID-19), trains and suburban railways were the cheapest means of public transport; aeroplanes – demonstrating dynamic growth in the number of passengers, excluding the period of the pandemic – were comparable to coaches in terms of cost, followed by underground trains, buses, and the common category of trams and trolleybuses. In spite of the lack of maintenance related to navigation routes, travelling by ship is ten times costlier than riding a train. The absolute majority of passengers (53-57%) chose the train for short distances (at most 30 km/travel), and the average distance ranged from 48 to 53 km between 2015 and 2021. The stock of passenger cars exceeded 4 million pieces in 2021 (71% of these were produced more than 10 years ago) and reached a share of 73% in road vehicles. Petrol cars accounted for 64.2%, diesel cars for 31.6%, hybrid cars for 2.9%, and electric cars for 0.5% of the total number of passenger cars. The remaining share of other fuels was 0.8% (*HCSO e-Shelf, 2022, Tables 4.5.4, 4.5.7, 5.6.5-5.6.6, 5.6.9-5.6.13, 5.6.23; HCSO, 2023a*).

8.2. Literature review

The research field of green mobility is frequently investigated; therefore, applying multiple refinements was required to reduce the number of articles to a manageable

quantity. The filters encompassed (i) document type (open-access articles), (ii) publication year (published between 2019 and 2023), (iii) language (written in English), (iv) keywords, terms ('green mobility'), and (v) research area (environmental sciences ecology, transport, business economics, urban studies, energy fuels, and development studies). Relying on all databases offered by the Web of Science and the conjunction of filters resulted in 651 hits, which formed part of a simplified systematic literature review. Twenty-nine papers were considered relevant, based on the bibliographic analysis, and they encompassed a broad range of individual and collective influencers and measures promoting green mobility in the EU and other developed countries with regard to residential routine mobility. Their synthesised union with overlapping dimensions is listed below with a particular travel mode or general scope. The circle of decision-makers is not indicated for the specific cases, as it can be comprehensive (e.g. individuals, providers, manufacturers, municipalities, legislative bodies). The determinants that can promulgate not only green mobility but also pro-environmental behaviour are the following:

1. macroeconomic, infrastructural, and demographic indicators of countries, e.g. GDP, length of bike lanes network, charging infrastructure for electric vehicles, stock of private cars, population density and growth, and prolongation of life expectancy *(Echeverria et al., 2022a, p. 256),*
2. the socio-economic profile of individuals, such as age, gender, family status, income, educational attainment, social-occupational group, nationality, and the area of residence *(Echeverria et al., 2022a, pp. 255-258; Enzler–Diekmann, 2019, p. 17; Herberz et al., 2020, p. 108; Hudde, 2022, p. 5),*
3. environmental (e.g. striving for an ameliorated air quality), financial (e.g. incentives, subsidies, price of passes or future fuel consumption), independence, status, hedonic, health benefit, and safety motives of individuals in mobility purchase intentions, making use of shared vehicles, or buying public transport tickets (*Herberz et al., 2020, p. 108*),
4. the psychological attachment to a private car, sharing it with members of the household, using multiple travel modes, the number of cars possessed by the household and their utilisation, and environmental aspects may induce the shift towards car sharing (*Briguglio–Formosa, 2023, pp. 1, 6, 9, 12*),
5. recreational activities, environmental concerns (e.g. climate change), the convenience of opting for specific travel modes (e.g. e-scooter), perceived safety during their usage and on roads in general, reducing congestion and noise pollution (e.g. based on the engine

noise level), lack of parking spaces, public transport shortcomings, and social influence (e.g. reference group, press) *(Kopplin et al., 2021, pp. 3-4, 8, 11),* complemented with the presumed causal chain of green attitudes, values, and loyalty *(Rodríguez-Correa et al., 2023, pp. 6, 13),*

6. previous experience gained in using travel modes *(Ko et al., 2021, p. 7),*

7. opting for active transport in order to achieve higher levels of well-being during travel (i.e. physical activity, lack of air pollution, impacts on mental health, and social contacts coupled with walking and cycling) *(Echeverria et al., 2022b, pp. 1, 5),*

8. corporate shared electric/hybrid cars for commuting to work (e.g. car sharing to events outside the firm) *(Julsrud–Standal, 2023, pp. 818-821)* and widening the composition of travellers, applying recommendation systems for ride sharing (e.g. matching commuters) (*Anagnostopoulos, 2021, p. 189*),

9. popularising the P+R (park and ride) concept, restricting vehicle transport (e.g. prohibition of motor vehicles in a specific region), and improving public transport (e.g. new or modernised routes, enhanced capacity for more passengers, less polluting vehicles with higher speed – meaning less travel time) *(Oleskow-Szlapka et al., 2020, p. 14),*

10. trip attributes (e.g. purpose, travelling companions), parking management strategies (e.g. free on-street parking for electric cars and restrictions for the rest), priority lanes for public transport and environmentally friendly individual vehicles, creating low emission zones (e.g. bans on the use of polluting vehicles in order to generate a modal shift towards green mobility), and enhancing pedestrian areas by addressing the problems posed by the ground gaining of cleaner vehicles (e.g. congestion, not participating in public transport or active modes) *(Gonzalez et al., 2022, pp. 1, 5, 14),*

11. the potential represented by applications (e.g. EcoAttivi smartphone application) in providing information about healthy and sustainable mobility along environmental (e.g. air pollution emissions), social (e.g. exchanging information, social media presence), organisational (e.g. trips, ticket purchase), and health (e.g. calorie intake for achieving an ideal weight, calories burned during physical activity, recommended duration and intensity of regular physical activity) dimensions *(Marquart–Schuppan, 2022, p. 6),*

12. low-carbon fuels and electricity (e.g. colour palette of hydrogen depending on its source), renewable energies (e.g. residential photovoltaic electricity), innovations (e.g. amphibious/floating buses for sightseeing tours, setting up an innovation department in the organisation), technologies (e.g. hybrid cars, hydrogen fuel cell, decreasing prices of electric vehicles thanks to progress, autonomous driving), their integration with

information and communication technology, the diffusion of digitalisation, technical readiness, availability of resources, economic viability, social acceptability, and environmental footprint *(Manakhov et al., 2022, pp. 1, 4, 12; Petrauskiene et al., 2020, p. 3),*

13. electricity storage (battery autonomy), creation and local industrial development of the automotive sector and/or other vehicle manufacturers, and battery recycling *(D'Adamo et al., 2023, pp. 848-849),*

14. green consumption values resulting in the reduction of pollution by changing mobility habits (e.g. a green band of manufacturers/providers triggers the intention to buy or rent their electric vehicles) *(Risitano et al., 2023, pp. 1096, 1105-1107),*

15. possessing driving licences (e.g. prerequisite of driving an e-scooter), business models (e.g. bike- or car-sharing) and in a wider context the supply side (e.g. availability of green alternatives on the same route, access to more flexible demand responsive vehicles, profound knowledge about travel options and vehicle design, features, and specifications, subsequently, the opportunity to purchase suitable vehicles in terms of size, fuel efficiency and further environmental awareness, etc.), and imposing emission standards on vehicles *(Dijk et al., 2019, pp. 65, 73),*

16. political preferences (e.g. voting for green parties), spatial factors (e.g. frequented sites such as universities or cultural institutions, distance to the most often visited destinations, the density of public transport stops, greenness of urban areas, tram tracks, or the railway and road network) *(Münzel et al., 2020, p. 251; ten Dam et al., 2022, p. 3)* or their simultaneous presence in near distance (e.g. green areas, bike or pedestrian lanes, university facilities, and public parking space for cars) *(Campos-Sanchez et al., 2019, p. 14),*

17. redistributing fiscal revenues for green mobility investments *(Goers–Schneider, 2019, p. 454),*

18. gender narratives by distinguishing between masculine (e.g. driving more and longer distances, power, speed, and status) and feminine (e.g. practical matters, less environmental harm and hence more openness for public transport and electric cars) stereotypical attributes associated with mobility *(Anfinsen et al., 2019, pp. 38, 45),*

19. suitable combinations of travel mode, business model (e.g. car-sharing), and propulsion (e.g. fossil fuel internal combustion engine or electric motor) *(Turon et al., 2022, p. 1),*

20. the current phase of innovation diffusion (e.g. Norway is expected to achieve the peak of electric car sales in 2024) (*Brdulak et al., 2021, pp. 6, 8, 12*),

21. the status quo, the relative strength of travel modes and business models (e.g. relative competitiveness of both the public transport system and traditional/electric two-wheelers compared to the private car regime or car-sharing in a larger city) *(Hjorteset et al., 2021, p. 8),*

22. disseminating knowledge, fostering participant networks and collaboration (e.g. industry alliances), planning and long-term commitments (e.g. roadmap with targets), establishing legitimisation and advocacy (e.g. influencing public views, political lobbying), creating markets (e.g. urban air mobility by means of electric vertical take-off and landing /eVTOL/ aircraft), mobilising and allocating resources (e.g. funding for infrastructure, training transport and vehicle engineers, urban designers, and landscape architects), launching reforms (e.g. modifying or devising legislation with the purpose of improved energy and GHG intensity, initiatives targeted at energy savings, implementing green waves of traffic lights) *(Trencher et al., 2021, pp. 4-7),*

23. using big data, simulation models (e.g. traffic congestion), optimisation problems (e.g. determining the timetable and the route of bus lines within a specific city), and machine learning techniques (e.g. predicting mobility patterns) *(de la Torre et al., 2021, pp. 5-6, 9, 12).*

Many preceding studies utilised a common fixed set of predictors, while this article follows a different path by enabling prevailing country specificities by means of tailored predictor selection. In accordance with my objective, this study aims at addressing the following research question (RQ):

Based on the experiences gained in selected European countries and the timeshare of preferred travel modes, what are the main influencing factors of replacing individual vehicles that use fossil fuel combustion in the residential routine mobility field?

8.3. Method

Quantitative analyses were carried out.

Ordinary least squares (OLS) linear regression, probit analysis, binary logistic regression, and artificial neural networks were used for prediction. Asymptotic independent samples z-tests were performed for comparing means.

OLS linear regression, probit analysis, binary logistic regression, and artificial neural networks were made in the statistical software IBM SPSS Statistics Version 27. The asymptotic independent samples z-tests were executed in Microsoft Excel.

8.4. Data collection

Between 2016 and 2019, the ENABLE.EU team undertook a project with the purpose of uncovering the drivers of individual energy choices and behaviours. The team compiled a questionnaire for conducting a household survey so that economic, social, cultural, geographical, and further institutional influencing factors could be revealed. The survey comprised seven sections: (i) home/building characteristics and household possessions, (ii) mobility, (iii) prosumers, (iv) heating and cooling, (v) electricity, (vi) governance, and (vii) social and economic characteristics. A total of 11,265 retail customers from eleven countries participated in the survey, of whom five (Hungary, Italy, Norway, Poland, and Spain) are relevant to this study owing to mobility data. The dataset contains 473, predominantly nominal and ordinal scale variables (*ENABLE.EU team, 2019*). Table 1 recapitulates the sections split by country.

Table 1. Dataset: available combinations of sections and countries (extract)

Country (abbreviation)	Home	Mobility	Prosumers	Heating and cooling	Govern-ance	Socio-economic	Number of respon-dents
Hungary (HU)	x	x	–	x	x	x	1,022
Italy (IT)	x	x	x	–	–	x	1,025
Norway (NO)	x	x	x	–	x	x	1,221
Poland (PL)	x	x	–	–	x	x	1,000
Spain (ES)	x	x	–	x	–	x	760
Total number of countries/records	5	5	2	2	3	5	5,028

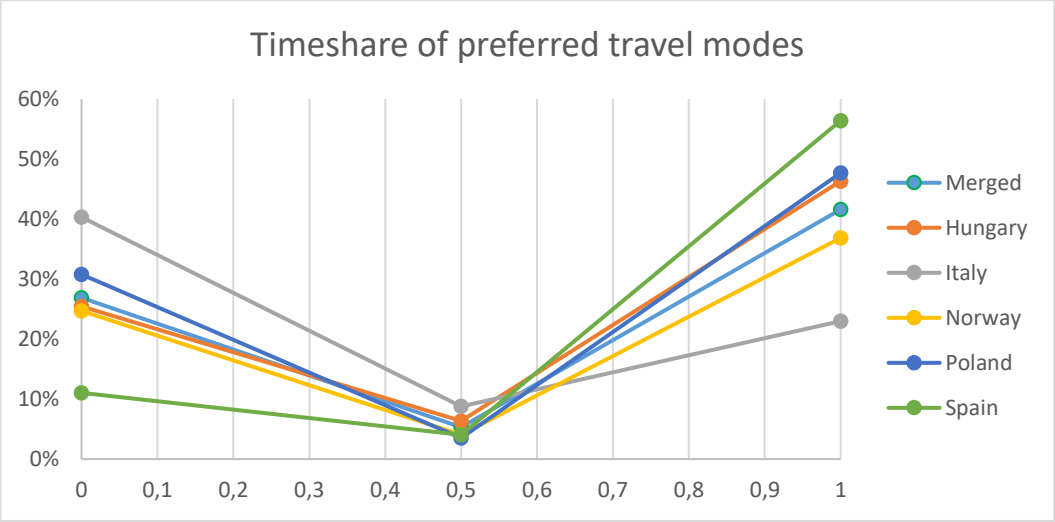
The sections on home/building characteristics and household possessions, mobility, governance, and social and economic characteristics bear importance for addressing the RQ. It is worth mentioning that amongst the five countries, Norway (5.504 million inhabitants at the end of the first quarter of 2023) is one of the countries with the highest number of electric vehicles in use worldwide. In 2022, the number of electric four-wheelers was 599 thousand units, and the stock of private cars was 2,917 thousand pieces. This implies that approximately 20.5% of the stock is composed of electric vehicles, corresponding to an estimate of 109 pieces per thousand inhabitants (*Statista, 2023; Statistics Norway, 2023a-2023b*). Due to the current share, Norway may serve as an appropriate case for illustrating the lessons learned during the penetration of electric cars.

8.5. Data analysis

In order to prepare data suitable for investigation by using the mentioned quantitative techniques, data transformation was performed as shown in the Table of the Annex.

The timeshare of preferred travel modes (TIME_SHARE_PREF_MODE) is a continuous variable ranging from 0 to 1. Only a subset of respondents (4,765 out of 5,028) indicated the needed data, necessary for the calculation of the variable. When analysing the dataset, three phenomena could be identified regarding single records. First, 37 Norwegian persons had at least one travel time field, where 1 day or more was registered. These fields are {M3(i)2_Time_(j)}, where i={A, B, C, D, E} and j={1, 2, ..., 11}. Second, the number of days was not known in the case of 33 Italian citizens; see the fields {M1(i)}, where i={A, B, C, D, E}. Third, the calculated destination-specific or total velocity was not plausible, as it exceeded the uniformly applied assumed speed limit of 140 km/h concerning 13 Norwegian or Spanish individuals. After removing 81 records[31] affected by at least one of these three limitations, 4,691 cases[32] remained in the dataset available for further analysis. Both Figure 1 and Table 2 characterise the distribution related to both the merged and the country-specific datasets. For the sake of transparency, Figure 1 illustrates the three most frequent values.

Figure 1. Partial histogram of the timeshare of preferred travel modes split by case



[31] The intersection of the limitations (i) and (iii) consists of 2 respondents, hence, the union comprises 37+33+13–2=81 elements.

[32] As mentioned earlier 5,028–4,765=263 persons did not fill in the needed questions entirely, thereof 7 Italians are part of the previously indicated 81 participants. Correspondingly, the final dataset incorporates 4,765–81+7=4,691 records.

Table 2. Descriptive statistics of the timeshare of preferred travel modes split by case

Statistics	Merged sample	Hungary	Italy	Norway	Poland	Spain
Mean	0.584	0.621	0.422	0.572	0.579	0.749
Median	0.667	0.833	0.429	0.640	0.750	1.000
Mode	1.000	1.000	0.000	1.000	1.000	1.000
Std. dev.	0.422	0.423	0.408	0.408	0.445	0.350
Sample size	4,691	991	878	1,110	969	743

Based on the asymptotic independent samples z-tests, the list of countries in decreasing order of timeshare of preferred travel modes begins with Spain (the timeshare amounts to 75% on average) followed by Hungary (62%) and the joint ranking of Poland and Norway (58%, 57%), while Italy (42%) lags behind. The dimension of the destination provided a ramification for research. Table 3 shows that travelling to the location of leisure activities (59.2%) and grocery/shopping (57.5%) has the highest timeshare of preferred modes, followed by the destinations of children's school (50.8%) and workplace/university (49.8%). Mobility decisions concerning the location of children's extra-school activities (42.2%) are the least conscious. Spaniards exemplify the most favourable country-destination pair in the comparative overview when they travel to the location of their leisure activities (82.0%).

Table 3. Mean of the timeshare of preferred travel modes by country and destination breakdown

Mean	Workplace/ university	Children's school	Children's activities	Grocery/ shopping	Leisure activities	General
Merged	0.498	0.508	0.422	0.575	0.592	0.584
Hungary	0.534	0.564	0.443	0.591	0.528	0.621
Italy	0.316	0.429	0.342	0.391	0.462	0.422
Norway	0.615	0.443	0.356	0.528	0.549	0.572
Poland	0.399	0.416	0.360	0.621	0.524	0.579
Spain	0.565	0.737	0.724	0.753	0.820	0.749

The available data render the prior formulation of the RQ more precise:

Based on the experiences gained in Hungary, Italy, Norway, Poland, and Spain, and the timeshare of preferred travel modes, what are the main influencing factors of residential routine mobility choices promoting public transport, electromobility, mobility sharing business models, biking, walking, and further environmentally friendly mobility solutions?

The avoidance of the introduction of dummy variables in the case of social and economic characteristics restricted the number of independent variables to the original

number of 7 instead of 7+17=24[33]. Prior to the runs carried out in SPSS, the presence of multicollinearity was controlled based on two statistics coupled with linear regression: (i) variance inflation factor (reciprocal of tolerance) and (ii) condition index. By entering 39 predictors in the model, collinearity was observed in the case of 11 regressors: (i) M5_time, (ii) M5_comfort, (iii) M5_flexibility, (iv) M5_privacy, (v) M5_air_quality, (vi) M5_CO2_emissions, (vii) M6_car-sharing, (viii) M6_P2P_car-sharing, (ix) M7_ financial_subsidy, (x) M7_tax_reduction, and (xi) M7_mobility_improvement when applying the rule of thumb of 2 as an acceptable limit for the VIF *(Kovács, 2014, p. 94)*. After removing 6 variables that caused disturbing multicollinearity from the model, 33 independent variables remained for further investigation. In parallel, none of the condition indices exceeded 5, i.e. the ceiling referring to tolerable weak multicollinearity *(Kovács, 2014, p. 95).*

The timeshare of preferred travel modes can be modelled by **OLS linear regression** *(Kovács, 2014, pp. 87-91)*:

$$\hat{y} = \hat{\beta}_0 + \sum_{i=1}^{m} \hat{\beta}_i \cdot x_i = \underline{\hat{\beta}}^T \cdot \underline{x} \qquad /1/$$

The total sum of squares is specified as:

$$SST = \sum_{j=1}^{n} (y_j - \overline{y})^2 \qquad /2/$$

The sum of the squared estimate of errors (residuals) is set to:

$$SSE = \sum_{j=1}^{n} (y_j - \hat{y}_i)^2 \qquad /3/$$

Adjusted R square is defined as follows:

$$R_{adj}^2 = 1 - \frac{SSE/(n-m-1)}{SST/(n-1)} \qquad /4/$$

where m represents the number of explanatory variables in the model and n is the sample size.

Testing the null hypothesis of zero beta coefficients relies on Student's t distribution:

$$t = \hat{\beta}_k \Big/ s_{\hat{\beta}_k} \qquad /5/$$

where k=0, 1, …, m and the number of degrees of freedom is ν=n–m–1.

Both binary logistic regression *(IBM, 2016, pp. 557-566)* and probit analysis *(IBM, 2016, pp. 797-801)* are appropriate tools for binary classification. A dichotomous

[33] Three variants: (i) without dummy variables: 7 variables, (ii) with dummy variables if the constant is not included: 7+17=24, and (iii) with dummy variables if the constant is included: 7+12=19 variables would be incorporated into the model. Here, variant (i) was chosen.

dependent variable is needed for logistic regression, ensured by eliminating the records differing from 0 or 1. In this study, the entire interval between 0 and 1 was investigated in order to reproduce the timeshare of preferred travel modes in the case of probit analysis. The regression parameters ($\underline{\beta}$ vector) are estimated in both cases with the maximum likelihood technique.

Binary logistic regression applies the logit transformation of the probability (i.e. the natural logarithm of the odds ratio), a linear function of the explanatory variables ($\underline{x}$ vector, which optionally contains 1 for the intercept), as shown below:

$$logit\, p(\underline{x}) = ln\left[\frac{p(\underline{x})}{1-p(\underline{x})}\right] = ln(odds) = \underline{\hat{\beta}}^T \cdot \underline{x} \qquad /6/$$

Based on /6/, the model can be expressed as follows:

$$p(\underline{x}) = \frac{\exp\left(\underline{\hat{\beta}}^{\mathrm{T}} \cdot \underline{x}\right)}{1+\exp\left(\underline{\hat{\beta}}^{\mathrm{T}} \cdot \underline{x}\right)} \qquad /7/$$

The formula of the general likelihood function in the ith step (n is the sample size):

$$l(i) = \prod_{j=1}^{n} p(\underline{x}_{ij})^{y_j} \cdot \left[1 - p(\underline{x}_{ij})\right]^{1-y_j} \qquad /8/$$

By applying N(y=1)+N(y=0)=n, this is equivalent to:

$$l(i) = \prod_{j=1}^{N(y=1)} \left(\frac{e^{\underline{\hat{\beta}}_i^T \cdot \underline{x}_{ij}}}{1+e^{\underline{\hat{\beta}}_i^T \cdot \underline{x}_{ij}}}\right) \cdot \prod_{k=1}^{N(y=0)} \left(\frac{1}{1+e^{\underline{\hat{\beta}}_i^T \cdot \underline{x}_{ik}}}\right) \qquad /9/$$

If the constant is not included in the model, the initial likelihood function *l(0)* can be computed as:

$$l(0) = \left(\frac{1}{2}\right)^n \qquad /10/$$

If the constant is included in the model, the formula of the initial likelihood function can be written as follows:

$$l(0) = \left(\frac{e^{\beta_0}}{1+e^{\beta_0}}\right)^{N(y=1)} \cdot \left(\frac{1}{1+e^{\beta_0}}\right)^{N(y=0)} \qquad /11/$$

where N(y=1)+N(y=0)=n.

Cox and Snell's R square in the ith step:

$$R_{CS}^2(i) = 1 - \left[\frac{l(0)}{l(i)}\right]^{\frac{2}{n}} \qquad /12/$$

Nagelkerke's R square in the ith step:

$$R_N^2(i) = \frac{R_{CS}^2(i)}{1-[l(0)]^{\frac{2}{n}}} \qquad /13/$$

Goodness-of-fit tests aim at assessing how accurately the predicted values represent the observations *(Canary et al., 2016, p. 675).* The Hosmer and Lemeshow goodness-of-fit statistic is a chi-square test:

$$\chi^2_{HL} = \sum_{k=1}^{g} \frac{(O_{1k}-E_{1k})^2}{E_{1k}\cdot\left(1-\frac{E_{1k}}{N_k}\right)} \qquad /14/$$

where k is the index of the group.

O_{1k} and E_{1k} symbolise the number of observed cases with y=1 and that of expected cases with y=1 in the k^{th} group. N_k stands for the total number of observations (both y=0 and y=1) in the k^{th} group, and their sum is equal to n.

The p-value represents the following probability:

$$p = \Pr\left(\chi^2 \geq \chi^2_{HL}\right) \qquad /15/$$

where the number of degrees of freedom is set to ν=g-2.

Testing the null hypothesis of zero beta coefficients relies on the z^2 distribution, which is a chi-square distribution with the number of degrees of freedom equalling 1:

$$Wald_k = \hat{\beta}_k^2 \Big/ s^2_{\hat{\beta}_k} \qquad /16/$$

where k=0, 1, …, m.

Probit analysis applies the cumulative distribution function of the standard normal distribution; transforms the sum of the intercept and the products of beta coefficients and predictors into a value between 0 and 1. The expected response $\hat{y}$ can be calculated as shown below:

$$\hat{y} = \Phi\left(\hat{\beta}_0 + \sum_{i=1}^{m} \hat{\beta}_i \cdot x_i\right) = \Phi\left(\underline{\hat{\beta}}^T \cdot \underline{x}\right) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\underline{\hat{\beta}}^T \cdot \underline{x}} e^{-\frac{z^2}{2}} dz \qquad /17/$$

By denoting the sample size with n, the Pearson goodness-of-fit test is a chi-square test whose test statistic is given by:

$$\chi^2 = \sum_{j=1}^{n} \frac{(y_j-\hat{y}_j)^2}{\hat{y}_j\cdot(1-\hat{y}_j)} \qquad /18/$$

The null hypothesis of good model fit can be declined if the test statistic exceeds the right-tailed value of $\chi^2_{1-\alpha}(\nu)$, where α is the significance level and ν is the number of degrees of freedom determined as ν=n-m-1.

In addition to the previous techniques, an **artificial neural network** method was designed *(IBM, 2016, pp. 607-616).* It is a machine learning method fit to be applied for regression, too. The multilayer perceptron is a feedforward, supervised learning network, a function of one or more predictors that minimises the prediction error of the dependent variable. The general architecture of multilayer perceptron networks consists of the input

layer, the hidden layer(s), and the output layer. SPSS restricts the number of possible hidden layers to two and offers three activation functions (hyperbolic tangent, sigmoid, and identity). The next notation was introduced: **x** vector of the predictors, *p* number of the independent variables, *q* number of the neurons in the 1st hidden layer, *r* number of the neurons in the 2nd hidden layer, *f* activation function of the hidden layer(s), *g* activation function of the output layer, *y* output, **w** matrix or vector of the synaptic weights (parameter estimates), b_0 scalar, and **b**, $\mathbf{b_1}$, or $\mathbf{b_2}$ vector of the parameter estimates for the biases (intercepts) in the 1st or 2nd hidden layer. The following formulae enable the calculation of the dependent variable:

Hyperbolic tangent: $h(x) = \tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}}$ /19/

Sigmoid: $h(x) = \frac{1}{1+e^{-x}}$ /20/

Identity: $h(x) = x$ /21/

The dependent variable for one hidden layer can be determined as follows:

$$y = g\left[\sum_{j=1}^{q} \mathbf{w}(\mathrm{j}) \cdot f\left(\sum_{i=1}^{p} \mathbf{w}(\mathrm{i,j}) \cdot \mathbf{x}(\mathrm{i}) + \mathbf{b}(\mathrm{j})\right) + b_0\right] \quad /22/$$

In the case of two hidden layers:

$$y = g\left\{\sum_{k=1}^{r} \mathbf{w}(\mathrm{k}) \cdot f\left[\sum_{j=1}^{q} \mathbf{w}(\mathrm{j,k}) \cdot f\left(\sum_{i=1}^{p} \mathbf{w}(\mathrm{i,j}) \cdot \mathbf{x}(\mathrm{i}) + \mathbf{b_1}(\mathrm{j})\right) + \mathbf{b_2}(\mathrm{k})\right] + b_0\right\} \quad /23/$$

The relative error is defined by the formula below (n is the sample size):

$$RE = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} = \frac{SSE}{SST} \quad /24/$$

The normalised importance of the independent variables is computed in two steps. First, the average of the highest distances is determined for each predictor i=1, 2, …, p by denoting $S_i = \{x_i^{min}, \ldots, x_i^{max}\}$ when using the input vector of the jth case as $\mathbf{x}_j = (x_j^1, \ldots, x_j^{i-1}, x_j^{ik}, x_j^{i+1}, \ldots, x_j^p)$:

$$d_i = \frac{1}{n} \cdot \sum_{j=1}^{n} \max_{x_{i1}, x_{i2} \in S_i} abs\left(\hat{y}_j^{i1} - \hat{y}_j^{i2}\right) \quad /25/$$

Second, the normalised importance – as a relative indicator – is set to:

$$NI_i = \frac{d_i}{max(d_1, \ldots, d_p)} \quad /26/$$

where i=1, 2, …, p.

Both Kolmogorov-Smirnov and Shapiro-Wilk tests were applied for testing for normal distribution. The null hypothesis of the normal distribution can be declined in each case. For this reason, the results of independent samples z-, t- or Welch tests are not valid for comparing means. The asymptotic independent samples z-test *(Hunyadi et al., 2000, pp. 468-469)* proves to be a viable alternative for testing the equality of means thanks to the

lack of such a prerequisite. This test requires merely finite standard deviations and large (sub)samples. In this study, (sub)sample sizes are above 600. A series of null hypotheses (H_0: $\bar{y} - \bar{x} = 0$) with the one-sided alternative hypotheses (H_1: $\bar{y} - \bar{x} > 0$) was carried out by dint of the formula of the asymptotic independent samples z-test. On the one hand, $\bar{y}$ denotes the higher value in question, and $\bar{x}$ refers to the corresponding lower value; on the other hand, $\delta_0 = 0$. Under the square root stand variances (s^2) and sample sizes (n) as specified in the formula below:

$$Z = \frac{\bar{y} - \bar{x} - \delta_0}{\sqrt{\frac{s_Y^2}{n_Y} + \frac{s_X^2}{n_X}}} \rightarrow N(0,1) \qquad /27/$$

8.6. Findings

In order to reproduce the timeshare of preferred travel modes ranging between 0 (0%) and 1 (100%), OLS linear regression, binary logistic regression, probit analysis, and an artificial neural network method proved to be the most appropriate techniques. For the sake of comparability amongst these four methods, TIME_SHARE_PREF_MODE was selected as the dependent variable without standardisation, while the predictors were uniformly standardised variables in each run.

The analysis begins with the simplest technique, i.e. OLS linear regression. First, making use of the highest possible number of regressors (33 out of 38) limited the circle of countries to Hungary, Norway, and Poland. Second, the investigation was restricted to the respective five national datasets. In order to determine the final models, an algorithm was utilised by removing the records from the datasets that met at least one of the four criteria below *(Kovács, 2014, pp. 96, 99-101)*:

a) The standardised residual is outside 3 standard deviations, here [–3,+3], as reported in the casewise diagnostics.
b) The Cook's Distance exceeds 1.
c) The estimation can be considered risky if the Centred Leverage Value is above 0.2.
d) Observations with a covariance ratio below 1–3p/n or above 1+3p/n require special attention.

In general, a model may be considered final if further cleaning of the dataset does not result in a better model fit and/or the subsequent model demonstrates anomalies (e.g. the stepwise variable selection estimates the number of four-wheel electric vehicles with

a negative beta parameter). When evaluating candidate models, a unified decision rule was not applicable; therefore, the model selection relies on different approaches, as described below.

Merged (Hungary, Norway, Poland): The run with the first local maximum of the adjusted R square was considered final, regardless of the number of standardised residuals outside 3 standard deviations.

Hungary: It was chosen considering that the adjusted R square exceeds 40% and the results are reasonably interpretable irrespective of the presence of standardised residuals outside 3 standard deviations.

Norway: The proportionally most abruptly waning sample size argued for achieving the first local minimum of the numbers of standardised residuals outside 3 standard deviations. In this particular case, the adjusted R square does not qualify as a local maximum.

Poland: The algorithm terminated when the first local maximum of the adjusted R square without any standardised residuals outside 3 standard deviations was attained.

Italy: Similarly, the first local maximum of the adjusted R square was sought, but the number of standardised residuals outside 3 standard deviations was disregarded.

Spain: The objective was simplified to obtain the first local maximum of the adjusted R square, as the issue of standardised residuals outside 3 standard deviations arose in none of the cases.

Table 4 recapitulates common phenomena and contrasts prevailing country specificities. Contradictory coefficients are marked with bold font type.

Table 4. Coefficients of the OLS linear regression models, cases excluded listwise, method: stepwise, dependent variable: TIME_SHARE_PREF_MODE (Sig.=p-value)

Countries involved in the final model	Merged (HU, NO, PL)			Hungary			Norway		
Initial set of independent variables	33			33			32[a)]		
Adjusted R square (%)	38.55			40.27			47.57		
Final sample size	585			364			86		
Number of regressors in the final model	8			6			5		
Variable	Beta	t-test	Sig.	Beta	t-test	Sig.	Beta	t-test	Sig.
Intercept	0.576	33.383	0.000	0.491	26.337	0.000	0.560	15.137	0.000
Zscore(NUM_FOUR_WHEEL_TRAD_VEH)	–0.265	–12.820	0.000	–0.332	–12.033	0.000	–0.136	–3.021	0.003
Zscore(M5_cost)	0.071	4.618	0.000	0.069	3.480	0.001			
Zscore(M5_flexibility)	–0.081	–5.022	0.000	–0.088	–3.994	0.000			
Zscore(SCORE_TRANS_SYS)	0.055	3.605	0.000				0.155	4.200	0.000
Zscore(SATIS_TRANS)	0.058	4.014	0.000						
Zscore(LESS_ENERGY_CONS)	0.064	3.357	0.001						
Zscore(S3-employment status)	0.080	5.028	0.000						
Zscore(S5-gender)	0.063	4.508	0.000	0.079	4.614	0.000			
Zscore(AGR_NEG_STAT)				**0.058**	2.703	0.007			
Zscore(M5_CO_2_emissions)				0.077	3.650	0.000			
Zscore(M5_availability)							**0.083**	2.222	0.029
Zscore(M5_time)							–0.128	–3.217	0.002
Zscore(S6-type of residence area)							–0.095	–3.052	0.003
Zscore(SEV_TRAF_PROB)									
Zscore(ASSESS_INFRASTR)									
Zscore(NUM_TWO_WHEEL_TRAD_VEH)									
Zscore(NUM_FOUR_WHEEL_ELEC_VEH)									
Zscore(age_2019)									
Zscore(M5_reputation)									
Zscore(S8-subjective evaluation of household's current income)									

(Table continues on the next page.)

(Continued.)

Countries involved in the final model	Poland			Italy			Spain		
Initial set of independent variables			33			28[b)]			28[c)]
Adjusted R square (%)			53.00			23.37			38.20
Final sample size			149			406			242
Number of regressors in the final model			8			7			7
Variable	Beta	t-test	Sig.	Beta	t-test	Sig.	Beta	t-test	Sig.
Intercept	0.707	16.006	0.000	0.441	20.441	0.000	0.712	34.386	0.000
Zscore(NUM_FOUR_WHEEL_TRAD_VEH)	–0.218	–5.837	0.000	–0.130	–5.772	0.000	–0.081	–3.800	0.000
Zscore(M5_cost)									
Zscore(M5_flexibility)	–0.155	–3.975	0.000						
Zscore(SCORE_TRANS_SYS)	0.090	2.720	0.007				0.118	6.314	0.000
Zscore(SATIS_TRANS)									
Zscore(LESS_ENERGY_CONS)	0.159	4.417	0.000	x			x		
Zscore(S3-employment status)	0.147	5.161	0.000	0.124	7.199	0.000	0.085	4.172	0.000
Zscore(S5-gender)									
Zscore(AGR_NEG_STAT)				–0.056	–2.735	0.007			
Zscore(M5_CO_2_emissions)									
Zscore(M5_availability)				–0.057	–3.223	0.001			
Zscore(M5_time)	**0.095**	2.725	0.007						
Zscore(S6-type of residence area)							–0.100	–5.492	0.000
Zscore(SEV_TRAF_PROB)	**–0.152**	–3.224	0.002				**–0.107**	–6.068	0.000
Zscore(ASSESS_INFRASTR)	–0.087	–4.113	0.000	x			x		
Zscore(NUM_TWO_WHEEL_TRAD_VEH)				0.042	2.316	0.021			
Zscore(NUM_FOUR_WHEEL_ELEC_VEH)				0.056	2.951	0.003			
Zscore(age_2019)				–0.048	–2.735	0.007			
Zscore(M5_reputation)							0.077	3.795	0.000
Zscore(S8-subjective evaluation of household's current income)							0.042	2.650	0.009

a) M7_financial_subsidy was discarded.

b) The five removed variables are LESS_ENERGY_CONS, PUBLIC_FIN_VEH, ASSESS_INFRASTR, PREF_TREAT_CARS, and NAT_POL_EFF.

c) The five removed variables coincide with those listed under the previous footnote.

In spite of the effort to find models conform with reality and environmentally conscious consumer behaviour, four paradoxes can be identified from the models based on OLS linear regression. These are denoted with (i)-(iv). The intercept can be interpreted as a systemic starting point, where Spain occupies the most propitious position regarding the timeshare of preferred travel modes (71.2%), whereas Italy represents the opposite pole (44.1%). The lack or a low number of four-wheel traditional vehicles (petrol cars, diesel cars, methane-fuelled cars, LPG-fuelled cars[34], vans, trucks, caravans) is salutary in each country; however, its impact deviates substantially to the disadvantage of Hungary and Poland. Attempting to reduce cost or attributing less importance to flexibility promotes environmentally friendly transport (e.g. public vehicles, bicycles, walking). Supporting government actions affecting the transport system (e.g. reducing emissions, creating bike lanes), satisfaction with transport facilities (e.g. public transport, public bike-sharing and car-sharing), and consuming less energy thanks to environmentally friendly alternatives (e.g. public transport, car-sharing, biking) imply a more elevated level of environmental awareness. Socio-economic characteristics such as employment status in favour of economically less active persons or gender in favour of women can contribute to greening mobility. (i) The first paradox is that the more a Hungarian agrees with negative statements about environmental issues (i.e. the readiness for acting now or making compromises in current lifestyle decreases), the higher the timeshare of preferred travel modes becomes. In contrast, the interrelationship in the case of Italy is exempt from it. Those who want to reduce CO_2 emissions give priority to greener travel modes. The wish for more availability supports the ownership of a vehicle with fossil fuel combustion; see the negative coefficient of Italy. (ii) Paradoxically, in Norway, the augmenting importance attributed to the availability of travel methods moderates the role of individual vehicles with fossil fuel combustion, presumably due to electric vehicles as a consequence of their high penetration. If travel time matters, the share of more air polluting modes is expected to rise, as in Norway. (iii) Nonetheless, in Poland, those who are evaluating travel time with a higher priority opt to a greater extent for preferred travel modes. The type of residence area can be a hindrance in the sense that living in rural areas can be coupled with less access to greener alternatives. (iv) As the fourth contradiction, the more citizens suffer from traffic problems (e.g. congestion, noise, local air quality), the less they travel by conveyances causing less environmental

[34] LPG stands for liquefied petroleum gas.

load. This assertion is valid for Poland and Spain. Assessing the infrastructure development positively over the last 3 years increases the inclination to choose public transport or electric vehicles, ride a bicycle, or walk. Both the number of two-wheel traditional vehicles (motorcycles, scooters, and non-electric bicycles) and that of four-wheel electric vehicles (electric cars and hybrid cars) are drivers. Younger customers are more likely to consider environmental concerns when making decisions about mobility. The good reputation of the methods of travel (e.g. public transport or electric vehicles) as an influencer may help in spreading attitudes beneficial for both nature and social well-being. Last but not least, financial difficulties support the transition, by renouncing the use of individual vehicles with fossil fuel combustion.

Binary logistic regression was performed by opting for the forward stepwise method based on conditional statistics. Only a subset of TIME_SHARE_PREF_MODE, i.e. the records, which equal 1 or 0, was apt for analysis. The algorithm applied to obtain the final model can be described as follows:

a) Primary criterion: The equation contains regressors and an intercept only if their beta coefficient can be considered significant at the 5% level. In addition, the null hypothesis of the Hosmer and Lemeshow test cannot be rejected.
b) If the primary criterion is met, the outliers outside 3 standard deviations have to be removed, and testing for the primary criterion is repeated.

The iteration is terminated when both criteria are fulfilled; hence, the final model is the first run with mere significant coefficients and an empty casewise list of standardised residuals. Table 5 aligns the results of the specific models. Again, bold font type refers to paradoxes.

Table 5. Coefficients of the binary logistic regression models, method: forward – conditional, dependent variable: TIME_SHARE_PREF_MODE with 0 and 1 values

Countries involved in the final model	Merged (HU, PL)			Hungary			Norway		
Initial set of independent variables	32[a)]			31[b)]			27[c)]		
Cox & Snell R square (%)	56.54			58.03			58.06		
Nagelkerke R square (%)	75.38			77.38			78.82		
Hosmer and Lemeshow test (p-value)	0.618			0.175			0.558		
Partial correct classification rate related to y=0 (%)	84.91			90.23			80.36		
Partial correct classification rate related to y=1 (%)	88.37			89.73			93.26		
Total correct classification rate (cut value=0.5) (%)	86.94			89.94			88.28		
Final sample size	513			318			145		
Number of regressors in the final model	10			9			7		
Variable	Beta	Wald	Sig.	Beta	Wald	Sig.	Beta	Wald	Sig.
Intercept	x	x	x	x	x	x	–1.532	5.386	0.020
Zscore(NUM_FOUR_WHEEL_TRAD_VEH)	–3.783	79.245	0.000	–4.924	45.822	0.000	–3.088	14.786	0.000
Zscore(NUM_TWO_WHEEL_TRAD_VEH)	0.668	13.534	0.000	0.812	12.066	0.001			
Zscore(M5_cost)	0.412	4.812	0.028	0.795	10.286	0.001			
Zscore(M5_flexibility)	–1.013	26.343	0.000	–0.807	10.318	0.001	–1.340	5.757	0.016
Zscore(SCORE_TRANS_SYS)	0.561	9.343	0.002	0.796	11.515	0.001			
Zscore(LESS_ENERGY_CONS)	0.856	19.165	0.000	0.801	8.656	0.003			
Zscore(ASSESS_INFRASTR)	–0.390	8.144	0.004						
Zscore(S3-employment status)	1.122	38.217	0.000	0.927	14.392	0.000			
Zscore(S5-gender)	0.834	24.642	0.000	0.879	15.802	0.000			
Zscore(S8-subjective evaluation of household's current income)	0.712	11.923	0.001						
Zscore(M5_safety)				–0.578	4.674	0.031			
Zscore(SEV_TRAF_PROB)									
Zscore(S6-type of residence area)							–1.563	15.016	0.000
Zscore(NUM_FOUR_WHEEL_ELEC_VEH)							1.580	11.297	0.001
Zscore(M5_time)							–1.014	5.354	0.021
Zscore(M5_CO_2_emissions)							0.672	3.920	0.048
Zscore(M5_reputation)							–1.573	7.856	0.005
Zscore(M5_availability)									
Zscore(age_2019)									

(Table continues on the next page.)

(Continued.)

Countries involved in the final model	Poland			Italy			Spain		
Initial set of independent variables			31[d)]			27[e)]			27[f)]
Cox & Snell R square (%)			56.55			39.39			16.32
Nagelkerke R square (%)			76.64			56.99			25.43
Hosmer and Lemeshow test (p-value)			0.105			0.271			0.707
Partial correct classification rate related to y=0 (%)			87.65			93.69			24.49
Partial correct classification rate related to y=1 (%)			91.27			69.05			97.30
Total correct classification rate (cut value=0.5) (%)			89.86			86.93			82.05
Final sample size			207			306			234
Number of regressors in the final model			8			4			3
Variable	Beta	Wald	Sig.	Beta	Wald	Sig.	Beta	Wald	Sig.
Intercept	2.500	21.237	0.000	–1.007	26.300	0.000	1.397	53.090	0.000
Zscore(NUM_FOUR_ WHEEL_TRAD_VEH)	–3.159	28.982	0.000	–1.937	37.722	0.000	–0.742	12.930	0.000
Zscore(NUM_TWO_ WHEEL_TRAD_VEH)									
Zscore(M5_cost)									
Zscore(M5_flexibility)	–1.921	15.123	0.000						
Zscore(SCORE_ TRANS_SYS)							0.685	13.323	0.000
Zscore(LESS_ ENERGY_CONS)	1.388	15.329	0.000						
Zscore(ASSESS_ INFRASTR)									
Zscore(S3-employment status)	1.607	25.928	0.000	1.462	49.515	0.000	0.776	12.221	0.000
Zscore(S5-gender)	0.542	4.279	0.039						
Zscore(S8-subjective evaluation of household's current income)									
Zscore(M5_safety)	1.043	6.734	0.009						
Zscore(SEV_TRAF_ PROB)	**–1.069**	5.224	0.022						
Zscore(S6-type of residence area)	–1.380	10.153	0.001						
Zscore(NUM_FOUR_ WHEEL_ELEC_VEH)									
Zscore(M5_time)									
Zscore(M5_CO_2_emissions)									
Zscore(M5_reputation)									
Zscore(M5_availability)				–0.665	13.759	0.000			
Zscore(age_2019)				–0.842	19.592	0.000			

a) SATIS_TRANS was discarded.

b) NUM_TWO_WHEEL_ELEC_VEH and SATIS_TRANS were discarded.

c) NUM_TWO_WHEEL_TRAD_VEH, AGR_NEG_STAT, M6_company_car, M7_ financial_subsidy, SATIS_TRANS, and PREF_TREAT_CARS were discarded.

d) SATIS_TRANS and S8 were discarded.

e) The six removed variables are SATIS_TRANS, LESS_ENERGY_CONS, PUBLIC_ FIN_VEH, ASSESS_INFRASTR, PREF_TREAT_CARS, and NAT_POL_EFF.

f) The six removed variables are identical with those enumerated in the previous footnote.

By deviating from the OLS linear regression models, Polish (best) and Norwegian (worst performing) citizens occupy the two extreme positions regarding the intercept. Hungarians adhere the most to four-wheel traditional vehicles, while Spaniards are the most inclined to switch to more environmentally friendly alternatives even if they possess this type of vehicle. Owning two-wheel traditional vehicles, considering travel cost and CO_2 emissions, supporting government actions affecting the transport system, and evaluating the household's current income less favourably exercise a positive impact. The unidirectional influence of flexibility varies between countries by cutting back on the timeshare of preferred travel modes, most strikingly in Poland. In contrast, if Polish customers are ready to consume less energy thanks to environmentally friendly alternatives, a higher timeshare can be achieved compared to their Hungarian counterparts. Negative assessment of infrastructure development, less urban type of residence area, attributing relevance to travel time, reputation, and availability of travel modes, and growing older are curbing the spread of environmentally friendly mobility. Being economically less active is an enabler, the gap between the economically active and inactive status is the narrowest in the case of Spanish citizens. Based on both the merged and Hungarian datasets, being female is nearly equivalent to consuming less energy thanks to environmentally friendly alternatives, while in Poland, the impact of the gender gap is moderated. The judgement of the safety of travel methods has conflicting effects: Polish people evaluate environmentally friendly mobility safer both in direction and intensity than Hungarians. One of the previous paradoxes repeats itself: the more Polish individuals are confronted by the severity of traffic problems, the less the share of preferred travel modes becomes. In Norway, having four-wheel electric vehicles has the highest positive coefficient, which is only half of the absolute value of the coefficient of traditional four-wheelers (see a similar relationship in Table 4 amongst the linear regression models in the case of Italy). A possible interpretation of the Norwegian model is that without further support, the spread of electric cars purchased by individuals may not be the salvation in the case of environmental problems stemming from transport. In addition, policymakers must reduce the time needed for travel with vehicles with less CO_2 emissions, improve their flexibility and reputation, and continue to widen the network of and increase access to environmentally friendly mobility in rural areas, according to the results.

The probit analysis was carried out in such a way that, first, the enter method was applied by relying on the maximum number of independent variables in order to select

the regressors bearing significant beta parameters at the significance level of 10%. Second, the run was repeated by involving these significant predictors and keeping the enter method. The loop terminated when the model contained solely variables with significant beta coefficients at the significance level of 5%. Table 6 summarises the main results. No contradictions were detected. The constant is by default included in the equations, and SPSS does not enable running models without intercepts. The final model based on the algorithm can be considered valid neither for the merged dataset due to the declined null hypothesis of good model fit nor for the Hungarian sample because of the insignificant intercept (see the concerned values marked with bold font type). For this reason, these models are only disclosed but not interpreted.

Table 6. Coefficients of the probit models, method: enter, dependent variable: TIME_SHARE_PREF_MODE

Countries involved in the final model	Merged (HU, NO, PL)			Hungary			Norway		
Initial set of independent variables	32[a)]			31[b)]			32[c)]		
Pearson goodness-of-fit test (p-value)	**0.000**			1.000			1.000		
Final sample size	2,310			990			1,082		
Number of regressors in the final model	8			3			2		
Variable	Beta	z-test	Sig.	Beta	z-test	Sig.	Beta	z-test	Sig.
Intercept	0.254	8.296	0.000	0.060	1.280	**0.201**	0.136	3.399	0.001
Zscore(NUM_FOUR_WHEEL_TRAD_VEH)	–0.703	–17.857	0.000	–0.985	–13.938	0.000			
Zscore(M5_cost)	0.098	3.282	0.001						
Zscore(M5_flexibility)	–0.250	–7.670	0.000						
Zscore(SCORE_TRANS_SYS)	0.116	3.829	0.000						
Zscore(LESS_ENERGY_CONS)	0.176	5.894	0.000						
Zscore(S3-employment status)	0.193	6.258	0.000						
Zscore(S5-gender)	0.159	5.418	0.000	0.257	5.670	0.000			
Zscore(S6-type of residence area)	–0.148	–5.113	0.000						
Zscore(NUM_TWO_WHEEL_TRAD_VEH)				0.109	2.266	0.023			
Zscore(NUM_FOUR_WHEEL_ELEC_VEH)							0.208	6.740	0.000
Zscore(M5_availability)									
Zscore(M5_time)							–0.090	–2.121	0.034
Remark	invalid model			invalid model					

(Table continues on the next page.)

(Continued.)

Countries involved in the final model	Poland			Italy			Spain		
Initial set of independent variables			31[d)]			28[e)]			28[f)]
Pearson goodness-of-fit test (p-value)			0.939			1.000			1.000
Final sample size			948			851			566
Number of regressors in the final model			3			4			3
Variable	Beta	z-test	Sig.	Beta	z-test	Sig.	Beta	z-test	Sig.
Intercept	0.214	4.479	0.000	–0.105	–2.014	0.044	0.665	10.340	0.000
Zscore(NUM_FOUR_WHEEL_TRAD_VEH)	–0.866	–12.879	0.000	–0.350	–6.507	0.000	–0.393	–5.382	0.000
Zscore(M5_cost)									
Zscore(M5_flexibility)									
Zscore(SCORE_TRANS_SYS)							0.199	3.069	0.002
Zscore(LESS_ENERGY_CONS)	0.188	3.530	0.000	x			x		
Zscore(S3-employment status)	0.364	7.899	0.000	0.365	7.932	0.000	0.357	4.912	0.000
Zscore(S5-gender)									
Zscore(S6-type of residence area)									
Zscore(NUM_TWO_WHEEL_TRAD_VEH)									
Zscore(NUM_FOUR_WHEEL_ELEC_VEH)				0.172	2.972	0.003			
Zscore(M5_availability)				–0.153	–3.390	0.001			
Zscore(M5_time)									

a) SATIS_TRANS was discarded.
b) SEV_TRAF_PROB and SATIS_TRANS were discarded.
c) M7_financial_subsidy was discarded.
d) SEV_TRAF_PROB and age_2019 were discarded.
e) The five removed variables are LESS_ENERGY_CONS, PUBLIC_FIN_VEH, ASSESS_INFRASTR, PREF_TREAT_CARS, and NAT_POL_EFF.
f) The aforementioned list of Italy is a duplicate of that applied to Spain.

The results of the probit analysis demonstrate many analogies with those of both the OLS linear regression and binary logistic regression. Considering the cumulative distribution function of the standard normal distribution helps in the interpretation of the beta parameters. Italy has the lowest average (42.2%, see Table 2), which provides an argument for its negative intercept. Four-wheel traditional vehicles function as the most important disabler, especially in Poland. Supporting government actions affecting the transport system (e.g. more attractive public transport) and consuming less energy thanks to environmentally friendly alternatives (e.g. abandoning the use of cars with fossil fuel combustion) propel the greening of the sector. Employment status proved to be the most important enabler in favour of economically less active persons, similar to binary logistic

regression. As perceived in the relationship in earlier cases, driving four-wheel electric vehicles improves the timeshare of preferred travel modes, but it lags far behind the four-wheel traditional vehicles in outstripping their impact according to the model of Italy. Nevertheless, individual fossil fuel consumption comes in the foreground when paying more attention to the availability of methods of travel or travel time.

Subsequently, multilayer perceptron networks explored the most important factors by executing the algorithm as follows:

a) Carrying out all combinations of available settings offered by SPSS (number of hidden layers /1, 2/, activation function for the hidden layer(s) /hyperbolic tangent, sigmoid/, activation function for the output layer /hyperbolic tangent, sigmoid, identity/) based on the full dataset by entering 33 variables (see the description under OLS linear regression) into each model resulted in a total of $2 \cdot 2 \cdot 3 = 12$ runs. Batch training with the scaled conjugate gradient optimisation algorithm and a training-test ratio of 100%-0% were applied.[35]

b) By making use of the decision rule of the lowest relative error, the architecture with (i) two hidden layers, (ii) the hyperbolic tangent activation function for the hidden layers, and (iii) the identity activation function for the output layer was selected as the most appropriate model, which was fixed for further runs.

c) The run was repeated on the trimmed dataset. The attribute ‘trimmed’ is used in the sense of keeping only the records whose residual is less than 0.2 in absolute value.

d) Country-specific runs based on trimmed datasets terminated the investigation by applying the previous rule for eliminating records.

Table 7 contains the normalised importance of all predictors by enabling cross-country comparisons so that country-specific phenomena can be identified. The percentages confirm the position of Norway as a forerunner, as it succeeded in interrupting the hegemony of four-wheel traditional vehicles as the most important influencer.

[35] The reason for opting for 100%–0% was the fact that the application of various training-test ratios (90%–10%, 80%–20%, 70%–30%) did not improve the fit of the model.

Table 7. Normalised importance of the independent variables, architecture with two hidden layers, the hyperbolic tangent activation function for the hidden layers, and the identity activation function for the output layer, dependent variable: TIME_SHARE_PREF_MODE, 100% training dataset

Variables↓/Countries→	Hungary, Poland	Hungary	Norway	Poland	Italy	Spain
Number of variables	32	32	32	31	28	28
Relative error	0.090	0.066	0.019	0.026	0.083	0.038
Training sample size	532	374	99	162	347	305
Zscore(NUM_FOUR_WHEEL_TRAD_VEH) (%)	100.0	100.0	93.3	100.0	100.0	100.0
Zscore(ASSESS_INFRASTR) (%)	67.8	60.9	41.3	60.3	x	x
Zscore(NUM_TWO_WHEEL_ELEC_VEH) (%)	56.8	68.5	51.3	25.0	79.7	67.7
Zscore(AGR_NEG_STAT) (%)	56.7	49.1	45.8	19.7	71.7	67.7
Zscore(M6_private_car_rental) (%)	51.1	20.4	47.5	59.3	72.4	74.4
Zscore(S2-highest level of completed studies) (%)	48.5	31.3	46.4	38.3	79.6	50.4
Zscore(M7_financial_subsidy) (%)	47.6	54.5	x	31.2	64.4	43.7
Zscore(M5_flexibility) (%)	46.9	32.0	19.4	75.2	56.2	36.0
Zscore(NUM_TWO_WHEEL_TRAD_VEH) (%)	45.7	38.5	16.6	29.1	60.9	41.7
Zscore(PREF_TREAT_CARS) (%)	45.0	40.5	58.1	36.1	x	x
Zscore(SATIS_TRANS) (%)	44.1	38.3	5.5	31.6	53.0	52.2
Zscore(PUBLIC_FIN_VEH) (%)	42.6	42.9	60.2	70.1	x	x
Zscore(M6_company_car) (%)	40.1	30.4	12.0	40.0	60.4	46.4
Zscore(M5_time) (%)	40.0	35.6	15.0	28.9	41.9	49.4
Zscore(S8-evaluation of household's income) (%)	37.6	48.7	15.8	28.7	60.3	54.4
Zscore(NAT_POL_EFF) (%)	37.3	25.0	50.4	14.5	x	x
Zscore(S3-current employment status) (%)	37.0	31.9	14.7	64.2	82.2	41.4
Zscore(M5_cost) (%)	36.5	51.3	48.9	35.7	64.1	44.3
Zscore(age_2019) (%)	36.3	37.3	15.3	26.0	67.5	56.8
Zscore(SEV_TRAF_PROB) (%)	34.6	37.5	46.2	82.3	68.5	62.7
Zscore(NUM_FOUR_WHEEL_ELEC_VEH) (%)	34.2	22.4	100.0	x	80.5	30.7
Zscore(SCORE_TRANS_SYS) (%)	32.2	52.9	62.7	58.0	73.3	68.0
Zscore(M5_reliability) (%)	31.5	33.8	29.5	49.5	68.3	45.5
Zscore(LESS_ENERGY_CONS) (%)	30.9	32.5	46.8	53.8	x	x
Zscore(S5-gender) (%)	29.5	23.1	8.2	13.0	39.9	19.1
Zscore(M5_CO_2_emissions) (%)	29.1	32.3	89.7	41.2	49.8	42.5
Zscore(M5_reputation) (%)	29.0	29.4	53.0	28.7	40.0	49.0
Zscore(M6_car-sharing) (%)	27.5	33.2	65.8	19.3	61.4	61.7
Zscore(S1-persons living in the household) (%)	27.3	46.4	29.6	44.5	37.4	65.6
Zscore(M5_safety) (%)	27.0	41.6	42.0	42.4	58.2	46.5
Zscore(S6-type of residence area) (%)	27.0	27.7	98.6	50.9	71.8	42.3
Zscore(M5_availability) (%)	22.1	45.7	16.7	21.4	73.1	50.2
Zscore(M6_bike-sharing) (%)	x	x	87.6	x	66.1	45.4

By setting a hypothetical minimum requirement of 40% for the normalised importance irrespective of countries (provided that the aspect is applicable and not counting the merged case of Hungary and Poland), (i) the number of four-wheel traditional vehicles, (ii) the assessment of infrastructure development, (iii) purchasing cars or motors from public means, (iv) supporting government actions affecting the

transport system, (v) ascribing importance to the safety of travel methods, and (vi) making use of bike-sharing constitute the circle of the main common determinants of environmentally friendly mobility. The variables attaining at least 80% normalised importance in one of the countries as salient influencers are the number of both (i) four-wheel traditional and (ii) four-wheel electric vehicles, (iii) the most typical current employment status, (iv) the severity of traffic problems, (v) placing emphasis on CO_2 emissions, (vi) the type of residence area, and (vii) utilising bike-sharing from the remaining predictors. The example of Norway suggests that factors such as the increasing endeavour of pairing down CO_2 emissions in mobility decisions and, correspondingly, both residential four-wheel electric vehicles and bike-sharing options will gain importance in the course of greening the transport sector.

8.7. Discussion

RQ: Based on the experiences gained in Hungary, Italy, Norway, Poland, and Spain, and the timeshare of preferred travel modes, what are the main influencing factors of residential routine mobility choices promoting public transport, electromobility, mobility sharing business models, biking, walking, and further environmentally friendly mobility solutions?

Table 8 shows the runs and clearly contrasts the results of valid models relying on different methods. The column of inconsistency indicates whether the variable in question is influenced by paradoxes, ambivalent impacts, or model dissimilarities along techniques.

Table 8. Range of coefficients, main common and salient determinants arising from the multilayer perceptron networks, and perceived inconsistencies

Zscore of variables (monotonicity of favourable values)↓/Technique→	Linear regression	Binary logistic regression	Probit analysis	Multilayer perceptron		Inc.
Regressand or type of determinant→	TIME_SHARE_PREF_MODE			Main common	Salient	
Set of values→	range: [0,1]	values: {0, 1}	range: [0,1]			
Intercept	[+0.441, +0.712]	[–1.532, +2.500]	[–0.105, +0.665]			
NUM_FOUR_WHEEL_ TRAD_VEH	[–0.332, –0.081]	[–4.924, –0.742]	[–0.866, –0.350]	x	x	
NUM_TWO_WHEEL_ TRAD_VEH	+0.042	[+0.668, +0.812]	–			
NUM_FOUR_WHEEL_ ELEC_VEH	+0.056	+1.580	[+0.172, +0.208]		x	
AGR_NEG_STAT (decreasing)	[–0.056, +0.058]	–	–			x
M5_cost	[+0.069, +0.071]	[+0.412, +0.795]	–			
M5_time	[–0.128, +0.095]	–1.014	–0.090			x
M5_flexibility	[–0.155, –0.081]	[–1.921, –0.807]	–			
M5_safety	–	[–0.578, +1.043]	–	x		x
M5_CO_2_emissions	+0.077	+0.672	–		x	
M5_availability	[–0.057, +0.083]	–0.665	–0.153			x
M5_reputation	+0.077	–1.573	–			x
SCORE_TRANS_SYS (increasing)	[+0.055, +0.155]	[+0.561, +0.796]	+0.199	x		
SEV_TRAF_PROB (increasing)	[–0.152, –0.107]	–1.069	–		x	x
SATIS_TRANS (increasing)	+0.058	–	–			
LESS_ENERGY_CONS (increasing)	[+0.064, +0.159]	[+0.801, +1.388]	+0.188			
ASSESS_INFRASTR (decreasing)	–0.087	–0.390	–	x		
S3-employment status	[+0.080, +0.147]	[+0.776, +1.607]	[+0.357, +0.365]		x	
age_2019	–0.048	–0.842	–			
S5-gender	[+0.063, +0.079]	[+0.542, +0.879]	–			
S6-type of residence area	[–0.100, –0.095]	[–1.563, –1.380]	–		x	
S8-subjective evaluation of household's current income	+0.042	+0.712	–			
M6_bike-sharing	–	–	–	x	x	
PUBLIC_FIN_VEH (increasing)	–	–	–	x		

Note: Inc.=Inconsistency.

Without reiterating the earlier disclosed interpretations, Table 8 outlines that seven areas form the intersection of the results through the lens of consistency:

(i) discouraging the possession (and use) of four-wheel traditional vehicles,

(ii) promoting the purchase of four-wheel electric vehicles,

(iii) raising awareness about CO_2 emissions so that individuals include this aspect in their mobility decisions,

(iv) supporting government actions affecting the transport system (e.g. by means of better communication),

(v) assessing the infrastructure development over the past couple of years in a positive way,

(vi) targeting and convincing employed people of the benefits of environmentally friendly mobility,

(vii) turning towards less urbanised territories and improving their access to green mobility.

Certain socio-economic determinants, such as age, gender, completed studies, employment status, income, and residence, are present in the research of *Echeverria et al. (2022a, pp. 255-258)*, *Herberz et al. (2020, p. 108)*, and *Hudde (2022, p. 5)*. In addition, *Herberz et al. (2020, p. 108)* pointed to the role of environmental, financial, independence (here availability), and safety motives. Concordant with Table 8, *Enzler–Diekmann (2019, p. 17)* concluded that income, economically active status, and owning traditional cars increase GHG emissions arising from mobility, while having environmental concerns (in this case, CO_2 emissions) and being female reduce them. Higher ages and living in a less urbanised area entail less GHG emissions, contrary to the findings related to the timeshare of preferred travel modes, by bearing in mind the dissimilarities between the two indicators. From a broader perspective, the low number of traditional four-wheelers and considering CO_2 emissions underpin the conclusions of *Briguglio–Formosa (2023, p. 12)* regarding car-sharing. By drawing on *Ko et al. (2021, p. 7)*, determinants of using shared mobility are car (non-)ownership, gender, and the satisfaction of such services (here a subset of SATIS_TRANS). *Oleskow-Szlapka et al. (2020, p. 14)* mentioned the improvement of public transport through investments, which is embodied in the score of supporting government actions affecting the transport system from an ecological viewpoint. Both *Kopplin et al. (2021, pp. 3, 11)* and *Marquart–Schuppan (2022, p. 6)* dealt with CO_2 emissions or environmental concerns. The aforementioned authors enumerated convenience (here to be interpreted as the mixture of

time, flexibility, and availability), safety, traffic congestion and noise (see SEV_TRAF_PROB), and shortcomings in both parking spaces and public transport (as part of SATIS_TRANS). One of the technological advancements *(Petrauskiene et al., p. 3)* is manifested in four-wheel electric vehicles. *D'Adamo et al. (2023, p. 848)* ranked purchase cost as the most critical factor in buying an electric car. Based on the ambivalent impact of reputation, the present study does not confirm that purchasing an electric vehicle can be a green band response *(Risitano et al., 2023, pp. 1105-1107)*. The supply side (here the ambivalent availability) and business models (in the results restricted to bike-sharing) formed part of the conceptual framework of *ten Dam et al. (2022, p. 65)*.

In order to explore the role of destination in mobility decisions, the general destination-independent approach is replaced by the destination-specific best practice, i.e. the case with the highest mean of timeshares. This is represented by Spain if the destination is leisure activities. Neither OLS linear regression nor probit analysis produced adequate models apt for use in merit. By applying the previous algorithm related to linear regression and keeping at least 55% of the records of the initial dataset, a low adjusted R^2, a non-informative model due to an intercept above 0.9, and the persistent presence of outliers in the dataset caused the failure. In the case of probit analysis, a model with one single significant predictor (agreeing with negative statements about environmental issues) and a significant intercept at the significance level of 5% was generated. Carrying out binary logistic regression repeated quasi-identical results (both in composition and coefficients) with those computed for the general timeshare of preferred travel modes: the number of four-wheel traditional vehicles and the score expressing the support of government actions affecting the transport system as independent variables complemented with an intercept. As the partial correct classification rate related to y=0 is slight (6.8%), this model is not appropriate for classification. The results of multilayer perceptron networks elucidate that general attitudes change when Spanish citizens travel to the location of their leisure activities, as shown in Table 9. In addition, it contains the figures related to the other destinations, but these are no more interpreted.

Table 9. Normalised importance of the independent variables split by destination, architecture with two hidden layers, the hyperbolic tangent activation function for the hidden layers, and the identity activation function for the output layer, 100% training dataset, Spain

Variables↓/Destination of travel→	General (i)	LA (ii)	Change in percentage points [(ii)–(i)]	W/U (iii)	CS (iv)	CA (v)	GS (vi)
Mean of timeshare of preferred travel modes	0.749	0.820	–	0.565	0.737	0.724	0.753
Number of variables	28	28	–	28	26	25	28
Relative error	0.038	0.016	–	0.028	0.301	0.001	0.045
Training sample size	305	258	–	211	55	41	273
Zscore(NUM_FOUR_WHEEL_TRAD_VEH) (%)	100.0	89.6	–10.4	78.4	48.1	3.6	83.9
Zscore(M6_private_car_rental) (%)	74.4	66.7	–7.7	100.0	x	x	80.6
Zscore(SCORE_TRANS_SYS) (%)	68.0	100.0	**+32.0**	97.7	61.6	85.3	90.1
Zscore(NUM_TWO_WHEEL_ELEC_VEH) (%)	67.7	48.4	*–19.3*	66.2	38.1	54.9	74.0
Zscore(AGR_NEG_STAT) (%)	67.7	95.2	**+27.5**	69.6	5.9	15.4	72.9
Zscore(S1-persons living in the household) (%)	65.6	60.5	–5.1	63.2	64.1	46.5	56.0
Zscore(SEV_TRAF_PROB) (%)	62.7	59.8	–2.9	72.7	35.2	57.8	58.0
Zscore(M6_car-sharing) (%)	61.7	56.8	–5.0	76.0	24.5	11.1	100.0
Zscore(age_2019) (%)	56.8	68.1	+11.4	47.7	1.3	3.6	39.8
Zscore(S8-subjective evaluation of household's current income) (%)	54.4	53.2	–1.2	60.7	100.0	100.0	50.0
Zscore(SATIS_TRANS) (%)	52.2	61.3	+9.1	73.9	34.2	4.4	51.8
Zscore(S2-highest level of completed studies) (%)	50.4	61.4	+11.0	67.3	48.1	90.2	61.4
Zscore(M5_availability) (%)	50.2	60.9	+10.7	64.6	25.5	1.0	22.2
Zscore(M5_time) (%)	49.4	56.5	+7.1	57.0	3.0	38.5	47.1
Zscore(M5_reputation) (%)	49.0	28.2	*–20.8*	42.7	16.8	16.6	58.4
Zscore(M5_safety) (%)	46.5	67.0	**+20.5**	46.6	8.8	73.8	50.3
Zscore(M6_company_car) (%)	46.4	41.4	–5.1	78.1	1.3	x	60.3
Zscore(M5_reliability) (%)	45.5	49.6	+4.1	68.0	48.6	59.5	44.9
Zscore(M6_bike-sharing) (%)	45.4	50.7	+5.3	94.5	0.6	0.3	55.4
Zscore(M5_cost) (%)	44.3	46.9	+2.6	48.6	3.6	28.1	42.0
Zscore(M7_financial_subsidy) (%)	43.7	88.2	**+44.6**	97.5	54.2	6.3	63.1
Zscore(M5_CO_2_emissions) (%)	42.5	40.2	–2.3	67.0	25.4	1.6	68.6
Zscore(S6-type of residence area) (%)	42.3	46.3	+4.1	47.9	31.1	2.2	51.3
Zscore(NUM_TWO_WHEEL_TRAD_VEH) (%)	41.7	31.6	–10.0	49.9	33.6	10.6	44.6
Zscore(S3-employment status) (%)	41.4	37.6	–3.7	30.2	2.2	1.1	41.5
Zscore(M5_flexibility) (%)	36.0	54.5	**+18.5**	45.7	36.3	50.8	51.8
Zscore(NUM_FOUR_WHEEL_ELEC_VEH) (%)	30.7	45.8	**+15.1**	64.7	x	x	33.1
Zscore(S5-gender) (%)	19.1	28.2	+9.1	48.1	1.9	12.6	31.5

Note: LA=Leisure activities, W/U=Workplace/university, CS=Children's school, CA=Children's activities, GS=Grocery/shopping.

Regarding leisure activities, at least a 15% point improvement (marked with bold font type) in normalised importance can be captured in the field of (i) supporting government actions affecting the transport system, (ii) agreeing with negative statements about environmental issues, (iii) the role of safety and (iv) flexibility in mobility decisions, (v) benefitting from a financial subsidy, and (vi) having four-wheel electric vehicles. Owning two-wheel electric vehicles and ascribing importance to the reputation of travel methods demonstrated at least the same level of shrinking (see figures written in italic font type) of the normalised importance. As Table 9 demonstrates, the normalised importance may vary in the function of the destination.

8.8. Conclusion, limitations, and further research

By performing OLS linear regression, enablers of green mobility are lower travel fares (decision based on cost), more supportive stance on government actions affecting the transport system, higher satisfaction with transport facilities, less energy consumption thanks to environmentally friendly alternatives, an economically less active employment status, being female, occupying a supportive position regarding environmental issues, considering CO_2 emissions and the reputation of preferred travel modes, citizens dwelling in urban areas, positive assessment of infrastructure development, possessing four-wheel electric and two-wheel traditional vehicles, younger age groups, and financial difficulties shifting people towards less air polluting modes. In contrast, the number of four-wheel traditional vehicles, less flexibility, less availability, and more travel time of preferred travel modes hinder the expansion of environmentally friendly transport. The impact of a few variables (e.g. owning four-wheel traditional vehicles) and the intercept deviates considerably amongst countries. The investigation revealed a few paradoxes, such as the way the severity of traffic problems is evaluated.

Binary logistic regression models demonstrated bold dissimilarities in the systemic initial point, the curbing impact of both possessing four-wheel traditional vehicles and the attachment to the flexibility of travel methods; furthermore, there were beneficial implications of the triad of consuming less energy thanks to environmentally friendly alternatives, economically less active status, and being female. By applying this technique, the safety of travel methods as the sole predictor proved to have conflicting effects. Additional enablers are having both two-wheel traditional and four-wheel electric vehicles, finding travel cost and CO_2 emissions important, supporting government actions

affecting the transport system, and encountering financial difficulties with regard to the household's current income. Conversely, disregard of infrastructure development, considering traffic problems more seriously, less urban type of residence area, accentuation of travel time, reputation, and availability of travel modes, and increasing age are slowing down the spread of environmentally friendly mobility.

Probit analysis demonstrated that the intensity of supporting government actions affecting the transport system, consuming less energy thanks to environmentally friendly alternatives, shifting towards an economically less active employment status, and having four-wheel electric vehicles are determinants with a positive impact. Possessing four-wheel traditional vehicles and the increasing role of both availability and travel time related to travel modes exercise a negative influence. In addition, noteworthy differences can be perceived in the systemic initial point: Italy and Spain represent the two opposite poles.

Multilayer perceptron networks revealed, based on the normalised importance, that the number of four-wheel traditional vehicles, the assessment of infrastructure development, purchasing cars or motors from public means, supporting government actions affecting the transport system, ascribing importance to the safety of travel methods, and making use of bike-sharing can be considered as the six main country-independent factors. In addition, the set of country-specific outstanding determinants consists of the number of four-wheel electric vehicles, the most typical current employment status, how severe traffic problems are perceived, the impact of CO_2 emissions on mobility decisions, and the type of residence area, complemented with the intersection of the two lists: number of four-wheel traditional vehicles and bike-sharing.

The general assertion that disablers can be transformed into enablers is valid in each case (e.g. enhancing the availability of public transport lines outside peak hours through an improved frequency and reducing the travel time by means of express bus lines and dedicated traffic lanes).

The results have some limitations. The set of predictors may not contain relevant variables. Such unobserved variables can be, e.g. values of the reference group related to owning four-wheel vehicles, objective circumstances such as health impairment, average number of passengers in four-wheel vehicles, professions requiring immediate access in emergency, impact of travel modes on health, and availability of alternative greener travel modes. The objective was the comparison of beta coefficients between both variables and methods; therefore, no interactions between variables were considered (e.g. interaction

between gender and air quality impact or between employment status and company car). Further model types (e.g. quadratic) may improve the fit of the model. The dataset may bear deficiencies, e.g. the low proportion of positive or affirmative answers in the case of specific variables of blocks M6 and M7. The commencement of the survey dates back to 2016; hence, the proliferation of preceding alternative electric or new electric vehicles such as Segways, unicycles, skateboards (e.g. hoverboards), skates, wheelchairs, furthermore, niche markets covering any type of water transport (e.g. motorboats) and air transport vehicles (e.g. planes of Texel, the largest Wadden Island in the Netherlands) owned by citizens were out of the scope of the survey. None of the questions targeted explicitly the national or international nature of travel. By estimating the total travel distance per week expressed in kilometres, it can be assumed that mostly urban and national interurban passenger transport was investigated. Less than 30 respondents indicated a total travel distance per week exceeding 1,000 km, which may qualify as national interurban transport in large countries such as Norway or as international transport in the case of persons residing in countries such as Hungary. The section on mobility did not consider holiday travels, while these holiday trips (especially by aeroplane) may cause a considerable part of the individual carbon footprint and thus could offer leeway for reduction. The weak fit of certain models, paradoxes, ambivalent impacts, and model dissimilarities along techniques mitigate validity. The sample cannot be considered representative, e.g. the citizens of Budapest are overrepresented based on the real distribution of the resident population (*HCSO, 2023b*). Finally, as country-specific phenomena prevail and the validity of assertions is restricted to the investigated countries, their broader applicability should be treated with reservation.

Within electromobility, a future research opportunity could be the spread of both four-wheel and two-wheel electric vehicles in the circle of residuals investigated from a broader perspective of environmentally conscious consumer behaviour (e.g. involving the section on prosuming or heating and cooling habits).

Mobility impacts the future development of societal well-being, environmental health, economic prosperity, and science. Deploying green and smart technologies in a citizen- and nature-centred way (e.g. social inclusiveness, improving the share of active modes as a remedy for sedentary lifestyles), engaging public opinion, and fading the hegemony of traditional vehicles with fossil fuel combustion promise to take the most benefit out of the mobility turn. By anticipating the future of carbon-neutral vehicles, the aspect of energy intensity may lose its relevance as a consequence of harnessing

inexhaustible energy sources. Autonomous vehicles may reshape the mobility scene into driverless roads, and by taking flight, urban air mobility may revolutionise human transport (e.g. shorter distances, higher speed, lack of congestion, no need for a built road network and its costly maintenance). By applying pro-environmental motivators, residential routine mobility can be transformed into regular active enjoyment with a plethora of benefits.

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Annex

The table contains the variables used for the analysis. On the one hand, the 39 utilised predictors and the 6 variables related to the timeshare of preferred travel modes, depending on the destination, are indicated. On the other hand, their composition has been added in case the original variable of the dataset provided by the ENABLE.EU team was transformed. The transformation of original nominal or ordinal scale variables enabled the creation of interval scale variables. For the sake of a better and more accurate interpretation of the affected newly introduced variables, each of their descriptions hints at the monotonicity of favourable values. Decreasing monotonicity means that the lower the value of a variable is, the more conscious the customer is, and vice versa. The statements listed in the questionnaire can be considered either positive or negative. To unify the points given to statements of both types, either the positive or the negative statements have been fixed depending on the underlying variable, and the opposite statements were transformed in such a way that their point was deducted from 6 (or 5) because of the possible range between 1 and 5 (or 1 and 4). In addition, the set of possible values in parentheses helps the reader in gaining insight into the range of responses.

Example for the interpretation of the table: In the case of AGR_NEG_STAT, smaller values are better due to decreasing monotonicity. A low total score expresses the inclination to act now or make compromises in the current lifestyle, while a higher total score hints at reluctance or their refusal.

Set of the original and transformed variables

Section	Name of the variable applied for the analysis [Brief description of the variable] /Monotonicity of favourable values/	Name of the original variables and their brief description
Home/Building characteristics and household possessions	NUM_FOUR_WHEEL_TRAD_VEH [number of four-wheel traditional vehicles owned by the household, values: {0, 1, …, 10}] =H4A+H4B+H4C+H4H–4	H4A [petrol car] H4B [diesel car] H4C [methane- or LPG-fuelled car[36]] H4D [electric car] H4E [hybrid car] H4F [motorcycle or scooter] H4G [electric motorcycle or scooter] H4H [van, truck, caravan] H4I [bicycle] H4J [electric bicycle] Values: {1 – do not have, 2 – one vehicle, 3 – two vehicles, 4 – at least three vehicles}
	NUM_TWO_WHEEL_TRAD_VEH [number of two-wheel traditional vehicles owned by the household, values: {0, 1, …, 6}] =H4F+H4I–2	
	NUM_FOUR_WHEEL_ELEC_VEH [number of four-wheel electric vehicles owned by the household, values: {0, 1, …, 5}] =H4D+H4E–2	
	NUM_TWO_WHEEL_ELEC_VEH [number of two-wheel electric vehicles owned by the household, values: {0, 1, …, 5}] =H4G+H4J–2	
	AGR_NEG_STAT [agreeing with negative statements about environmental issues] /decreasing/ =H15A+H15B+H15C+(5–H15D)+ +H15E Discrete values: {5 – strongly disagree, 6, …, 20 – strongly agree}	H15A [refusing to act] H15B [environmental impacts being overstated] H15C [shifting problems towards future generations] H15D [making compromises in current lifestyle] H15E [not partaking in financial consequences of environmental policies] Values: {1 – strongly disagree, 2, 3, 4 – strongly agree}

(Table continues on the next page.)

[36] LPG stands for liquefied petroleum gas.

(Continued.)

Mobility	TIME_SHARE_PREF_MODE [timeshare of preferred travel modes, general] /increasing/ Range: [0,1] $= \frac{\sum_{i=A}^{E} M1(i) \cdot [\sum_{k \in \mathcal{H}} M3(i)2\_Time\_(k)]}{\sum_{i=A}^{E} M1(i) \cdot [\sum_{j=1}^{11} M3(i)2\_Time\_(j)]}$	M1(i) [weekly number of days split by destination, 5 variables] M3(i)2_Time_(j) [time needed to travel to destination i by travel mode j, 55 variables] (i) is the index of the most frequent destinations, i=A, …, E, where: A – workplace/university, B – children's school, C – location of children's activities, D – grocery/shopping, E – leisure activities. $\mathcal{H}$ is the set of travel modes without individual vehicles with fossil fuel combustion, $\mathcal{H} \in \{3, 5, \ldots, 11\}$, (j) and (k) are the indices of travel modes, j=1, …, 11, k∈$\mathcal{H}$, where: 1 – petrol or diesel car, 2 – methane- or LPG-fuelled car, 3 – electric or hybrid car, 4 – motorcycle or scooter, 5 – carpooling, 6 – bus, 7 – train, 8 – metro/tram, 9 – bicycle, 10 – walking, 11 – other (e.g. boat, ferry).
	TIME_SHARE_PREF_MODE_WU [timeshare of preferred travel modes when travelling to workplace/university] /increasing/ Range: [0,1] $= \frac{M1A \cdot [\sum_{k \in \mathcal{H}} M3A2\_Time\_(k)]}{M1A \cdot [\sum_{j=1}^{11} M3A2\_Time\_(j)]}$	
	TIME_SHARE_PREF_MODE_CS [timeshare of preferred travel modes when travelling to children's school] /increasing/ Range: [0,1] $= \frac{M1B \cdot [\sum_{k \in \mathcal{H}} M3B2\_Time\_(k)]}{M1B \cdot [\sum_{j=1}^{11} M3B2\_Time\_(j)]}$	
	TIME_SHARE_PREF_MODE_CA [timeshare of preferred travel modes when travelling to the location of children's activities] /increasing/ Range: [0,1] $= \frac{M1C \cdot [\sum_{k \in \mathcal{H}} M3C2\_Time\_(k)]}{M1C \cdot [\sum_{j=1}^{11} M3C2\_Time\_(j)]}$	
	TIME_SHARE_PREF_MODE_GS [timeshare of preferred travel modes when travelling to grocery/shopping] /increasing/ Range: [0,1] $= \frac{M1D \cdot [\sum_{k \in \mathcal{H}} M3D2\_Time\_(k)]}{M1D \cdot [\sum_{j=1}^{11} M3D2\_Time\_(j)]}$	
	TIME_SHARE_PREF_MODE_LA [timeshare of preferred travel modes when travelling to leisure activities] /increasing/ Range: [0,1] $= \frac{M1E \cdot [\sum_{k \in \mathcal{H}} M3E2\_Time\_(k)]}{M1E \cdot [\sum_{j=1}^{11} M3E2\_Time\_(j)]}$	
	Importance of factors when opting for travel methods: M5_cost [importance of cost] =M5A M5_time [importance of travel time] =M5B M5_comfort [importance of comfort] =M5C M5_flexibility [importance of flexibility] =M5D M5_safety [importance of safety] =M5E M5_privacy [importance of privacy] =M5F M5_air_quality [importance of air quality] =M5G M5_CO2_emissions [importance of CO_2 emissions] =M5H M5_reliability [importance of reliability] =M5I M5_availability [importance of availability of method] =M5J M5_reputation [importance of reputation] =M5K Discrete values: {1 – not at all important, 2, 3, 4, 5 – very important}	M5(i) [importance of factors when opting for travel methods, 11 variables] (i) is the index of factors, i=A, …, K, where: A – cost, B – travel time, C – comfort, D – flexibility, E – safety, F – privacy, G – air quality impact, H – CO_2 emissions impact, I – reliability, J – availability of method, K – reputation. Values: {1 – not at all important, 2, 3, 4, 5 – very important}

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Mobility	M6_company_car [use of a company car] =M6A M6_car-sharing [use of car-sharing] =M6B M6_P2P_car-sharing [use of peer-to-peer car-sharing] =M6C M6_bike-sharing [use of bike-sharing] =M6D M6_private_car_rental [renting a private car] =M6E Discrete values: {1 – never, 2 – occasionally, 3 – often, 4 – always}	M6(i) [frequency of use of mode, 5 variables] (i) is the index of modes, i=A, …, E, where: A – company car, B – car-sharing, C – peer-to-peer car-sharing, D – bike-sharing, E – private car rental. Values: {1 – never, 2 – occasionally, 3 – often, 4 – always}
	M7_financial_subsidy [type of subsidised vehicle] =M7A M7_tax_reduction [type of vehicle to which a tax reduction can be attributed] =M7B M7_mobility_improvement [type of vehicle affected by mobility improvement] =M7C Discrete values: {1 – petrol or diesel car, 2 – methane- or LPG-fuelled car, 3 – electric car, 4 – hybrid car, 5 – bicycle, 6 – electric bicycle, 7 – bus, 8 – not received}	M7(i) [benefitting from help or advantage assigned to vehicle type, 3 variables] (i) is the index of help or advantage, i=A, B, C, where: A – financial subsidy, B – tax reduction, C – mobility improvement. Values: {1 – petrol or diesel car, 2 – methane- or LPG-fuelled car, 3 – electric car, 4 – hybrid car, 5 – bicycle, 6 – electric bicycle, 7 – bus, 8 – not received}
	SCORE_TRANS_SYS [score of supporting government actions affecting the transport system from an ecological viewpoint] /increasing/ $= (6 - M8A) + \sum_{i=B}^{H} M8(i)$ Discrete values: {8 – strongly opposed, 9, …, 40 – strongly supportive}	M8A [building and expanding roads] M8B [discouraging automobile use] M8C [bike lanes and speed controls] M8D [tests and manufacturer emissions standards] M8E [faster public car-sharing and public transport] M8F [more attractive public transport] M8G [reducing transport distances] M8H [compressed working weeks and home office] Values: {1 – strongly opposed, 2, 3, 4, 5 – strongly supportive}
	SEV_TRAF_PROB [severity of traffic problems] /increasing/ $= \sum_{i=A}^{G} M9(i)$ Discrete values: {7 – not at all important, 8, …, 35 – very important}	M9A [traffic congestion] M9B [traffic noise] M9C [excessive presence of vehicles] M9D [local air quality] M9E [accidents due to drivers] M9F [global warming] M9G [unsafety due to speeding traffic] Values: {1 – not at all important, 2, 3, 4, 5 – very important}

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Mobility	SATIS_TRANS [satisfaction with transport facilities] /increasing/ $= \frac{\sum_{i \in \mathcal{H}} M10(i)}{n(\mathcal{H})}$ Range: [1 – very low, 5 – very high]	M10A [parking space] M10B [public transport timetables] M10C [public transport coverage] M10D [bike lanes] M10E [pedestrian lanes] M10F [public bike-sharing] M10G [public car-sharing] Values: {1 – very low, 2, 3, 4, 5 – very high, 6 – not applicable} $\mathfrak{H}$ is the set of answers ranging from 1 to 5 and n($\mathfrak{H}$) is the cardinality of the set $\mathfrak{H}$.
Governance	LESS_ENERGY_CONS [less energy consumption thanks to environmentally friendly mobility alternatives] /increasing/ =G1A1+G1A2 Discrete values: {0 – worst, 1, 2 – best}	Two binary variables: G1A1 [new car with low fuel consumption] G1A2 [walking, biking, public transport, car-sharing] Values: {0 – no, 1 – yes}
	PUBLIC_FIN_VEH [purchasing cars or motors from public means] /increasing/ =n($\mathfrak{H}$) Discrete values: {0 – worst, 1, 2 – best}	G3B [public means used for electric or hybrid cars] G3E [public means used for motor vehicles meeting higher environmental standards] Values: {1 – yes, 2 – no, 3 – not applicable} $\mathfrak{H}$ is the set of answers equalling 1 (yes) and n($\mathfrak{H}$) is the cardinality of the set $\mathfrak{H}$.
	ASSESS_INFRASTR [assessing the development of the infrastructure over the last 3 years] /decreasing/ $= \frac{\sum_{i \in \mathcal{H}} G4(i)}{n(\mathcal{H})}$ Range: [1 – it has improved significantly, 5 – it has worsened significantly]	G4A [public transport, inclusive underground, metro] G4B [bicycle lanes] G4C [pedestrian zones] G4D [public shared bicycles] G4E [public charging stations for electric vehicles] Values: {1 – it has improved significantly, 2, 3, 4, 5 – it has worsened significantly, 6 – not applicable} $\mathfrak{H}$ is the set of answers ranging from 1 to 5 and n($\mathfrak{H}$) is the cardinality of the set $\mathfrak{H}$.
	PREF_TREAT_CARS [preferential treatment of cars causing less air pollution] /decreasing/ =G5A+G5C+G5E Discrete values: {3 – totally agree, 4, …, 15 – totally disagree}	G5A [severe limitations in city centres for cars causing air pollution] G5C [smaller taxes after cars meeting higher environmental standards] G5E [tax exemption or tax relief when purchasing an electric or hybrid car] Values: {1 – totally agree, 2, 3, 4, 5 – totally disagree}

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Governance	NAT_POL_EFF [evaluation of the effectiveness of national policies regarding energy from renewable energy sources and climate change] /monotonicity is not classified due to subjective or country-specific factors/ =G6C+G6E Discrete values: {2 – very successful, 3, …, 10 – very unsuccessful}	G6C [increasing the share of energy from renewable energy sources] G6E [climate change mitigation] Values: {1 – very successful, 2, 3, 4, 5 – very unsuccessful}
Social and economic characteristics	S1 [total number of persons living in the household for at least 6 months of the year, values: {0, 1, …, 37}] =S1Ac1+S1Ac2+S1Ac3+S1Bc1+S1Bc2+ +S1Bc3	S1Ac1 [women under the age of 18 years] S1Ac2 [women aged between 18 and 65 years] S1Ac3 [women older than 65 years] S1Bc1 [men under the age of 18 years] S1Bc2 [men aged between 18 and 65 years] S1Bc3 [men older than 65 years]
	S2 [highest level of completed studies] Discrete values: {1 – below primary education, 2 – primary education, 3 – secondary and post-secondary non-tertiary education, 4 – bachelor or master, 5 – PhD}	
	S3 [most typical current employment status] Discrete values: {1 – economically active: full-time, 2 – economically active: part-time, 3 – without employment for more than 3 months, 4 – economically inactive: retired, 5 – economically inactive: student, 6 – economically inactive: other remaining categories}	
	age_2019 [age attained in 2019 based on calendar year difference, values: {17, 18, …, 97}] =2019–S4	S4 [year of birth]
	S5 [gender] Discrete values: {1 – male, 2 – female}	
	S6 [type of area of residence] Discrete values: {1. A city with more than 0,5 million inhabitants: in its centre, 2. A city with more than 0,5 million inhabitants: outside its centre, 3. A town or a city with less than 0,5 million inhabitants, 4. A village, 5. Cases not listed above, e.g. farm in the countryside}	
	S8 [subjective evaluation of household's current income] Discrete values: {1. Enabling living comfortably, 2. Coping with financing the current standard of living, 3. Difficulties when financing the current standard of living, 4. Severe difficulties when financing the current standard of living}	

Source: (*ENABLE.EU team, 2019, pp. 3, 6, 7-13, 23-26*)

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III. MAIN FINDINGS AND EPILOGUE

9. Summary

Taking again examples from Greek mythology and history serves as a thought-provoking opening for the epilogue. Theseus did not get lost in the Minotaur's Labyrinth at Knossos on Crete as after fighting his battle, he could find the way back to the entry of the maze with the help of the thread received from Ariadne, daughter of King Minos. The humanity of the 21st century is struggling to cope with global challenges and perils. Human activities have reached such a pitch (e.g. see global annual GHG emissions or impacts causing bleaching of coral reefs) that fundamental interventions will be unavoidable to halt or reverse catastrophic ongoing processes and their calamities on humanity. Opposite to the Hellenic hero, mankind does not need to enter any battle or to return to the initial point but keep walking on the unpaved way of sustainable development and accomplish this unprecedented transformation as we can see light at the end of the tunnel. Achievements of ancient civilisations that flourished thousands of years ago are comparable with many fields of the SDGs. During the blossom period of the peninsula of Attica and in general, that of Hellas, agriculture, handicraft, trade, education, disciplines, culture, architecture, human settlements, democracy, diplomacy against common threats, sport, and hygiene are a few areas bearing noteworthy results. Gender equality was in a nascent phase, see e.g. the Olympic Games or the low number of female famous personalities such as the poet Sappho. Wealth inequalities dominated, e.g. only the reachest (pentacosiomedimnoi) were eligible for the highest positions in Athenian government. In spite of the lower level of technology, less favourable health conditions, more inequalities, and frequent conflicts, they could meet the concise requirement of sustainable development based on its widely known definition provided in the report titled 'Our Common Future'. Both society and economy could prosper and citizens living in harmony with nature did not need to get familiar with the purport of such notions as planetary boundaries. Oddly, they faced environmental problems (e.g. massive deforestation to produce ships for their wars) as well.

As outlined in Chapter 2. Theoretical background, the relevance of the topic is underpinned by harmful, unsustainable or ongoing processes. In addition, Table 23 draws

on the last available statistics. These processes can be summed up with a few areas highlighted below:

- the prevalence of circulatory system diseases being the leading cause of death in Hungary and the role of risk factors in causing fatal outcomes (*OECD–EOHSP, 2023, pp. 5, 7*);
- the digital agenda related to SMEs (*OECD, 2021a, 2021b*);
- the gap between consumption and biologically productive resources in Hungary (*GFN, 2023b*);
- Act on climate protection 2020, XLIV lays down the milestones of the decarbonisation pathway in Hungary by leaving ample room for manoeuvre when targeting actors (*NLD, 2023f*);
- both Health and well-being (3rd SDG) and Tackling climate change (13th SDG) are below time-proportionate requirements (*Sachs et al., 2023, pp. 36-37*);
- six out of nine planetary boundaries are transgressed (*Richardson et al., 2023*);
- global warming can trigger multiple climate tipping points (*McKay et al., 2022*);
- alarming forecasted sectoral impacts of changes in climate parameters in the Carpathian Basin for the 21st century (*MIT, 2020a, pp. 4-5, 17-18*);
- climate and further environmental challenges can escalate into a source of instability and severe threats (e.g. political conflicts, food insecurity, forced migration, or redefined economic, trade, and security interests) (*EC, 2019, p. 21*).

Table 23 reiterates the main messages of the articles, the findings emphasise the pivotal role of single actors (individuals and SMEs). It excerpts those statements from the main findings of the articles that bear novelty.

23. Table: Extended abstracts of the studies

Summation, primary geographical scope, recent statistics, relation to preceding research, presumed new scientific findings, discussion, implications for stakeholders, and future research opportunities

No.	Description
1st	**Summation**: Good health greatly depends on the lifestyle of citizens, but applying a positive approach in the argumentation targeting mitigating behavioural risks may prove to be more effective in preserving and prolonging their health as it can substantially reduce the prevalence of cardiovascular diseases. **Scope**: Explicit countries are Hungary, the Czech Republic (both representing countries at high cardiovascular risk), and Austria (low cardiovascular risk), but the results can be taken over. **Recent statistics**: Circulatory system diseases, reaching a share of 42.3% of all cases in 2021, were the leading cause of decease in Hungary. In 2019, 24% of all fatalities could be traced back to unhealthy diet. Tobacco use was responsible for 21% of all deaths, both alcohol consumption and air pollution /restricted to fine particulate matter ($PM_{2.5}$) and ozone exposure/ accounted for 7-7% of mortalities while low physical activity was the reason for death regarding 2% of the cases. (*OECD–EOHSP, 2023, pp. 5, 7*) **Relation to preceding research***:* Probabilities for the occurrence of fatal cardiovascular events within 10 years are available, however, more health consciousness and rising life expectancy are likely to be obtained by applying the new proposed positive approach, preceding akin research was not found. From a broader perspective, the study can be assigned to the category of articles analysing the relationship between health risk factors and an aggregate variable such as health-related costs, all-cause mortality or productivity (here in specific life expectancy). **Presumed novelty**: Communicating mortality rates due to cardiovascular diseases can be replaced by an effective risk assessment tool that can provide an easily interpretable metric and hence, strengthen the preventive components of corporate well-being programmes in order to diminish cardiovascular risks. Free-to-download tables (see http://www.ksh.hu/statszemle_archive/en/2021/2021_01/2021_01_017_annex.xlsx) align the life expectancies for each health status to the benefit of citizens of the three mentioned countries: A1 – Hungary, A2 – Czech Republic, and A3 – Austria. Each table enables individuals to select a starting and a target health status for a given combination of gender, age, smoker status, systolic blood pressure, and total cholesterol, then, to estimate the gains in life expectancy as their difference. **Discussion:** Only a feasibility check could be carried out because of a lack of similar studies. ANN was an appropriate choice for reproducing the 10-year cardiovascular mortality rates and filling in the missing values between 40 and 65 years and beyond this range as values demonstrate a reasonable fit with the initial data. **Academic implications**: In order to achieve both the maximum life expectancy and maximum healthy life expectancy at the level of society, priority should be given to research targeting two fields: 1. obtaining the best available health and 2. preventing illnesses.

	Implications for policymakers: When allocating resources to particular areas of the health system, strengthening prevention and earlier stages of the disease pathway can provide the most benefit. **Practical implications**: By making use of simple behavioural risk assessment, individuals can be more aware of their health risks and after identifying outdated habits, they can shift towards recommended practices. Companies can improve the preventive component of their health promotion programmes. **Further research**: 1. Similar risk assessment tools can be created for other risk types in order to enhance the effectiveness of prevention. 2. The country comparison points to a presumed phenomenon that within the country group at high risk, improving effective primary prevention and public health care may result in more harvestable gains for individuals striving towards the best health status. On obtaining the low cardiovascular rates and passing into the eminent low-risk country group, the general system-level improvement provides more realisable increments for individuals in less favourable health statuses.
2nd	**Summation**: Spurring firms lagging behind on the digital pathway combined with deploying environmental management enhances their competitiveness. Accelerating the spread of green(er) technologies in the most polluting industries could substantially abate air pollution and harm to societies. **Scope**: The findings bear relevance with particular reference to Hungary. **Recent statistics:** In the circle of SMEs, both environmental protection and ICT are neglected: their position is amongst the back office functions (e.g. controlling). An equal share of 68% of the respondents declared that these areas have a significant contribution to the performance of companies. 16%-16% evaluated their contribution moderate. (*Chikán et al., 2019, p. 41*) Albeit 67.4% of the total number of persons employed worked at SMEs (incl. microenterprises) in 2022, they could realise – partly due to being less competitive – an underproportionate share in net turnover (35.4%), turnover from export sales (12.3%), and value added (43.9%). (*HCSO, 2023b*) **Relation to preceding research***:* Former research investigated the following areas related to SMEs: the effects of digitalisation on sustainability, the relationship between ICT use and environmental performance, measuring the digital maturity, determinants of digital transformation, factors hindering the innovation activity of enterprises /see 3.a) below/, the relationship between firms' capabilities and competitiveness or particularly its subset, i.e. the link between digital preparedness and competitiveness /see 3.b) below/, etc. **Presumed novelty**: 1. The proposed illustrative maps help in evaluating industries and manufacturing branches by means of air pollutant emission intensities. They indicate both the simultaneous reduction of various emissions and the most critical areas. 2. The contribution of the second article is the creation of principal components as a form of dimension reduction. Principal components of digitalisation incorporate (i) preparedness for digitalisation, (ii) corporate level of digitalisation, (iii) digitalisation applied by leading enterprises of the industry, (iv) basic digitalisation tools, (v) advanced digitalisation tools, and (vi) technology use

	and change. The principal components of environmental protection comprise (i) basic environmental management tools, (ii) advanced environmental management tools, (iii) environmental and social aspects of sustainability, (iv) sustainability performance compared to competitors, and (v) procurement. Tables 6 and 7 of the second article give profound insights into the content of each principal component. 3.a) More competitive companies are more intensely affected by a shortage of qualified workforce, impeding their innovation activity. 3.b) More competitive companies outperformed the less competitive ones in all investigated dimensions, except for three subareas: (i) digitalisation applied by leading enterprises of the industry, (ii) advanced digitalisation tools, and (iii) basic environmental management tools. Two within-group phenomena can be identified. First, deepening digitalisation or environmental protection (except for procurement) promotes the competitiveness of less competitive firms. Second, if better group membership is attained, the positive impact of advancement in the principal components of competitiveness ceases to exist. **Discussion:** 1. The critical areas partly coincide with the list of difficult-to-decarbonise sectors. 2. Due to model specificities, a comparison of the findings with structures arising from other studies did not take place. 3. a) In 2018 in the EU-28, 56% of SMEs encountered difficulties due to the shortage of ICT specialists. A split along competitiveness is not available. (*DESI 2020, 2021, p. 12*) 3. b) Informatics are declared mandatory for remaining competitive by 62% of the respondents of the CRC survey. Informatics can ensure a competitive advantage for a short period (13% of the companies) or even longer duration (3%). (*Chikán et al., 2019, p. 26*) *Csesznák–Wimmer* (2021, pp. 145-147) indicated a positive significant interrelatedness between competitiveness and digital preparedness, irrespective of the basic properties of firms. Therefore, it is not confirmed that advanced digitalisation tools are not differentiating. During 2006–2008, more than 40% of the companies in the CRC sample invested in environmental protection. It can be presumed that since then, thanks to the progress made over the last decade and a half, basic environmental management tools have become a must. (*Chikán et al., 2010, p. 33*) As alternative methods, it was made use of the creation of indices, the calculation of Pearson correlation coefficients and concomitant tests of zero correlation, and running a series of non-hierarchical cluster analyses. **Academic implications**: As differences in impacts arise depending on the specific measure and the initial level of corporate competitiveness, involving corresponding dimensions can be justified when scrutinising corporate competitiveness. **Implications for policymakers**: More tailored policies (e.g. target groups and supported areas) can be devised when deciding on the funding to enhance both environmental protection (e.g. problematic industries and branches) and digitalisation (e.g. mitigating the digital gap related to the company size) in the circle of SMEs.

	Practical implications for SMEs: By identifying weaknesses, SMEs lagging behind can improve their competitiveness by making advancements on the digital pathway combined with deploying environmental management based on a recipe for success consisting of a set of best-practice measures. **Further research**: Relevant directions can be designated by (i) GHG or CO_2 emissions, (ii) propelling springs of digitalisation and the estimate of its potential for decarbonisation, and (iii) influencers of the commitment to the circular economy.
3rd	**Summation**: People demonstrating a higher degree of environmental consciousness (e.g. due to being apprehensive of future generations and nature) began to make use of more sustainable alternatives except for particular facets of mobility and governance. Heightening awareness in the circle of less conscious customers is indispensable so that these solutions can become mainstream practices. **Scope**: The findings bear relevance with particular reference to Hungary. **Recent statistics:** Several selected indicators valid for Hungary can capture the progress made in the last four decades and the necessary future efforts to achieve climate neutrality: 1. Both the GHG and CO_2 emissions of the households remained in 2021 in the midst of temporary ameliorations slightly above the levels of 1985. (*HCSO, 2023a*) Total GHG emissions per capita amounted to 6.7 t CO_2-equivalent in 2021. (*Destatis, 2023b*) 2. CO_2 emissions per unit of GDP in 2020 equalled 0.14 kg CO_2 per 2010 USD of GDP. (*UNECE, 2024*) 3. Both per capita CO_2 emissions embodied in imports (1.8 t, 2018) and per capita CO_2 emissions from fossil fuel combustion and cement production (the latter is a hard-to-abate sector) (5.0 t, 2021) demonstrate an aggravating trend. (*Sachs et al., 2023, p. 271*) 3. Apart from a few exceptions, the country overshoot day of Hungary is worsening. In 2023, it occurred on the 30th of May which is equivalent to 2.4 Earths (case of assuming Hungarian consumption patterns worldwide). (*GFN, 2023b*) **Relation to preceding research***:* Environmental conscious consumer behaviour is a frequently analysed and profoundly explored research area. The present scrutiny joins the numerous analogous antecedents unifying the attributes of two grouping themes represented by (i) comparative studies (along the level of consciousness) and (ii) influencers of sustainable consumption patterns. The aim was to classify consumers along environmental consciousness and collect their cluster-specific characteristics. The peculiarity lies in the feature of enabling stakeholders to conceive targeted approaches when raising awareness /see 1 below/. **Presumed novelty**: 1. This study attempted to delineate the type of customer appertaining to various levels of environmental awareness by virtue of selected fields of the sections on home, mobility, heating and cooling, plus governance. Tables 7 (combinations of proposed actions and affected clusters representing a certain level of environmental awareness at a significance level of 10%) and 9 (distribution of the clusters based on social and economic characteristics) of the third article provide orientation when deciding on the details of actions to be carried out. None of the clusters can be considered as a paragon as the more environmentally aware a customer is, the more favourable values can be achieved except for (i) the share of preferred travel mode, (ii) the total travelled

	distance per week, (iii) less energy consumption regarding mobility and household appliances, and (iv) accepting the inconvenience arising from environmentally friendly measures. **Discussion:** The majority of findings gained reinforcement compared with the selected articles. The literature review confirmed the findings related to prices, communication, national specificities, demographic and socio-economic characteristics, being aware of energy efficiency programmes, initial cost and allowance in the spread of solar energy systems, cost of devices and the price of grid electricity, emphasising realisable energy savings and economic benefits, technology, practices, knowledge, and behaviour in heating and cooling. The susceptibility to CO_2 emission reductions proved to be dual: it is confirmed concerning governance, but refuted with regard to mobility. Previous research pointed to the differentiating role of gender, while the negation of this assertion was concluded in this study. Additionally, the asymptotic independent samples z-test was utilised as an alternative method. **Academic implications**: Offering suggestions in such a way that they can be translated into precise actions facilitates their implementation. **Implications for policymakers**: Decision-makers can conceive targeted approaches when raising awareness by relying on the combinations of proposed actions and affected clusters. The clusters – representing a certain level of environmental awareness – are described by the distribution of their social and economic characteristics. **Practical implications for consumers**: In addition to self-classification, individuals striving to heighten their environmental awareness can identify areas needing improvement. **Further research**: More profound insights into slices of single sections (home, mobility, heating and cooling, plus governance) can be provided.
4th	**Summation**: Applying a tailored approach may promote the spread of prosumers. With regard to modifiable circumstances, a prosumer pathway can be outlined in the course of unfolding environmental awareness. It starts with being a traditional customer without PV plans in the near future, then shifts towards having PV plans, and finally, the customer becomes a prosumer. **Scope**: The validity of the findings may vary depending on the countries Italy, Norway, Serbia, Ukraine, and the United Kingdom. **Recent statistics:** Regarding the state of renewable energy sources in 2020 in Hungary, solid biomass dominates by reaching 70% of the use of primary renewable energy sources. In contrast, modern renewables still demonstrate low shares: hydro – 1%, wind – 2%, geothermal – 5%, and solar – 8% within primary renewable energy sources. The proportion of solar energy from total electricity use amounted merely to 5.3% in 2020 while the preponderance of heating can be observed with respect to the purpose of use of renewables in final energy use in the circle of households. The residential share of final energy use was around 32-34% between 2018 and 2020. In spite of favourable geographical conditions, the structure of Hungarian primary energy use is characterised by considerable imports resulting in a permanent risky import dependency above 50%. (*HCSO e-Shelf, 2022, Tables 4.5.2, 4.5.4-4.5.7*; *HCSO, 2023a*)

	Relation to preceding research*:* On the one hand, the article can be placed amongst the studies revealing the enablers (including the role of information and professional advice) and disablers of the diffusion of PV technology /see 1 and 3 below/, on the other hand, it explores the profile of consumers along the stages of becoming a prosumer /see 1 below/. Finally, it posits a few context-specific comparative conclusions /see 2 below/ by hinting at dissimilarities between countries. **Presumed novelty**: 1. The curiosity of the study is that it expands the dichotomy (being prosumer or not) to three stages. Hence, the comparative analysis investigates the relationships (i) between prosumers and traditional customers, plus (ii) between traditional customers with PV plans in the near future and those without such intentions. The common findings are valid in the context of both (i) and (ii): a) The respective more conscious group is better educated and has a more stable financial background. b) Its members achieved a higher proportion of energy-efficient bulbs inside their homes, which are on average single-family houses attached to building(s). c) These dwellings are more likely to be equipped with smart meters. d) They consume less energy thanks to environmentally friendly alternatives and agree more strongly with the inconvenience arising from eco-friendly measures. Additional statements referring to the relation (ii): Traditional customers with PV plans have a larger family, demonstrate a higher share of men and more commitment to environmental issues, and are younger and economically more active than their counterparts without plans. 2. Prosumers give priority to formal information channels (one-sided p-value: 6.01%) when acquiring information about PV systems. Both in the circle of prosumers and those with PV plans in the near future, technological reasons are the least motivating drivers of installation, followed by environmental and finally by other (e.g. financial) motives. 3.a) The article identified general phenomena with distinctive dissimilarities between Western and Eastern states in the aspect of size and current income of the household, use of energy-efficient bulbs and smart meters, less energy consumption due to mobility and household appliances, and accepting the inconvenience coupled with environmentally friendly measures. 3.b) With a focus on the United Kingdom and Serbia, further differences could be revealed: (i) Serbia demonstrates a weak negative (one-sided p-value: 6%), whereas the UK a stronger contradictory positive association between the number of routines for own energy conservation actions and the evaluation of factors detaining other people from saving electricity. (ii) These two variables proved to be independent when distinguishing traditional customers along PV plans in the near future on the merged dataset of the two states. (iii) and (iv) British individuals with PV plans have more routines for energy savings and overestimate others' passive attitudes more than citizens without such intentions. In Serbia, these dissimilarities are not significant.

	3.c) The comparison between Norway and Italy pointed to significant country specificities regarding the weekly total travelled distance, opting for environmentally friendly mobility, supporting government actions affecting the transport system, and estimating the severity of traffic problems. **Discussion:** 1. As an alternative approach, logistic regression was applied but the models cannot be used for prediction due to slight true positive rates. Based on the literature review, the conclusions from the comparison are research-dependent. Studies can be found that confirm the relationship between becoming a prosumer and each of gender, age, family size, type of building or a broader definition, type of education, using LEDs, installing energy-saving household appliances, monthly expenditures on electricity, and income. Articles with oppositional results exist as well e.g. in terms of floor area, monthly average net income, changing the provider, and having a smart meter. 2: Preceding research recommended to give priority to non-economic policies instead of economic ones. It gained confirmation that ecological factors fell behind economic ones. A study applying a dynamic view elucidated that an alteration in main motives may occur over time: first, environmental reasons, then, economic drivers. 3: The asymptotic independent samples z-test was used to validate the findings of hypotheses (2) and (3). The positive relationship between the propensity for pro-environmental behaviour and actions to reduce energy use is already unveiled. Knowledge about GHG emissions and energy savings is a major determinant of the number of activities related to reducing energy consumption. This is in line with hypothesis (2). No preceding research could be assigned to hypotheses (1) and (3). **Academic implications**: Applying a trichotomous approach in investigations about prosumerism is closer to reality in view of the dissimilarities of the three stages. **Implications for policymakers**: The recent geopolitical events elucidated the vulnerability of the domestic power supply. Programmes on the spread of PV microinstallations can be shaped more adequately for the target group of retail customers in terms of both popularisation and needs. **Practical implications for consumers**: Albeit good wine needs no bush, as the old saw goes, the penetration of solar panels is still slow (at least in Hungary). The article steers attention to the exploitation of plentifully available domestic renewable energy sources for retail use so that the CO_2 emissions of households can be pared down. **Further research**: The interrelatedness between electric energy consumption and each stage of the three-stage prosumer pathway (prosumers, traditional customers with PV plans in the near future and those without such intentions) is of interest as it is reasonably assumed that prior to installing PV systems, the use of electricity is reduced and energy efficiency is improved.
5th	**Summation**: Numerous alternatives enable us to promote environmentally friendly mobility (e.g. public transport, individual electromobility, mobility sharing business models, biking, and walking). Even disablers can be turned into stimuli. **Scope**: Experiences gained in Hungary, Italy, Norway, Poland, and Spain were evaluated.

Recent statistics: The GHG intensity (g CO_2-equivalent/passenger km) of passenger transport modes argues for opting for public transport and reducing the use of cars and aviation. (*IEA, 2023b*) Transportation and storage caused approximately 10% of the total GHG emissions of the Hungarian national economy in 2021. (*HCSO, 2023a*) In Hungary, the share of transport in final energy consumption showed a slight deviation from 27% between 2018 and 2021. (*HCSO, 2023g*) Renewable energy sources in transport accounted for less than 12% of total gross final energy consumption in the same period. (*HCSO, 2023h*)
Relation to preceding research*:* The article joins the series of studies addressing determinants of green residential routine mobility by putting the research field in a broad international comparative context and hinting at dissimilarities in the outcomes of identical tools. By dividing arbitrarily corresponding preceding research into four dimensions, the collective and individual levels are affected, while the dimension of the technological background and the corporate level are left out.
Presumed novelty: The main influencing factors of residential routine mobility choices promoting environmentally friendly mobility solutions can be country-independent or country-specific, additionally, paradoxes may arise. Drivers are known from previous studies, thus, the list below is not novel, it is only one of their possible collections.
Unidirectional (A) and ambivalent (B) determinants are identifiable. (A) (i) Importance of cost, (ii) supporting government actions developing the transport system, (iii) satisfaction with transport facilities, (iv) less energy consumption thanks to environmentally friendly alternatives, (v) economically less active employment status, (vi) being female and (vii) of younger age, (viii) considering CO_2 emissions, (ix) dwelling in urban areas, (x) assessing positively infrastructure development, (xi) possessing four-wheel electric and (xii) two-wheel traditional vehicles, and (xiii) coping with financial difficulties impel people to opt for less air polluting modes. In contrast, (i) owning four-wheel traditional vehicles, (ii) less flexibility of preferred travel modes, and (iii) increasing severity of traffic problems impede their spread.
(B) The results are accompanied by a few paradoxical findings in terms of (i) safety, (ii) availability, and (iii) reputation of travel methods, (iv) travel time, and (v) being a proponent of environmental issues.
Outside the previous categorisation, (i) purchasing cars or motors from public means and (ii) making use of bike-sharing are further factors.
Discussion: The results of valid models were contrasted by relying on different methods. Paradoxes, ambivalent impacts, and model dissimilarities along techniques were identified. Preceding research disclosed numerous influencing factors which are repeatedly revealed by confirming them. These are certain socio-economic determinants (e.g. age, gender, employment status, income, and residence); environmental concerns, financial, independence, and safety motives; supply side and business models; car (non-) ownership, the low number of traditional four-wheelers, the purchase cost of four-wheel electric vehicles; the satisfaction of shared mobility services; the improvement of public transport through investments; convenience, traffic congestion and noise, and

	shortcomings in both parking spaces and public transport. Based on the ambivalent impact of reputation, the present study does not confirm that purchasing an electric vehicle can be a green band response. **Academic implications**: The findings widen the list of determinants of green mobility by hinting at paradoxes, ambivalent impacts, and dissimilarities along techniques and countries. **Implications for policymakers**: The article offers recommendations on how to promote public transport, electromobility, mobility sharing business models, biking, walking, and further environmentally friendly mobility solutions. **Practical implications for consumers**: Getting familiar with influencing factors may sharpen the view of individuals so that they attribute more importance to preferred travel modes. **Further research**: Within the field of environmentally conscious consumer behaviour, an interesting theme is contrasting holiday travel with residential routine mobility. Another future research opportunity could be the spread of both four-wheel and two-wheel electric vehicles in the circle of residuals investigated from a broader perspective by involving e.g. prosuming or heating and cooling habits).
	Overarching further research: The triad of health consciousness, environmental awareness, and financial intelligence is a possible representation of the three subsystems. A future scrutiny may unveil how these levels simultaneously can be improved.

Our epoch was pregnant with a lack of foresight in terms of excessive material output emerging from human activities and deterioration of the biosphere, thus, humanity left its grave mark on the surface of Earth. From an abstract viewpoint, the current global polycrisis and how we deal with it can teach us and our successors a historical moral lesson. Difficulties caused by humans should be solved by themselves in order to refind harmony with our sole precious vital planet (what we once had but temporarily lost) and undergo the inseparable physical-mental-spiritual transformation (e.g. better health, more commitment and perseverance, respecting and loving nature) to restore our individual balance as well. The dilemma between occupying the optimum by preserving still existing prosperous circumstances (accepting /quasi-/stacionarity next to new areas of growth) or accepting a forced optimum-like situation in a decaying world argues for abandoning ostrich policy or the policy of small steps. More and immediate consciousness at all levels may predispose stakeholders to pre-empt further deleterious consequences or competitive drawbacks compared to best practices in many fields, participate in initiatives, and harvest the benefits, which surpass the required efforts in volume (see e.g. the proportion between the investments related to climate mitigation and their benign impacts). Despite unfavourable projections, the 1.5-degree scenario is still achievable by means of more stringent pledges and their consequent realisation. Even a marathon with a distance of approximately 42 kilometres starts with the first step but those who run the race (with or without companions) can gain stamina, physical fitness, mental strength, and further impressions and experiences. In analogy with sport, the hindrances of our era can be considered as opportunities to be recognised and seized. Instead of procrastinating acting now, voting for the SDGs and, in particular, preferring mitigation in the field of decarbonisation enable their followers amongst others to apply an exemplary toolkit. It ensures health and well-being, getting committed to lifelong learning, making use of the advantages of sustainable urbanisation, deploying state-of-the-art technologies (e.g. renewable energy), and becoming more resilient against shocks on the long term well beyond the target year of 2030 and with an expanded outlook for future generations. I wish all of us entering this virtuous circle as soon as possible.

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11. Appendix

24. Table: The SDGs and their targets

Index	Content of the SDG and its targets (extract) (Only 126 out of 169 targets are listed.) (*United Nations, 2015, pp. 15-27*)
1	**Ending poverty**: 1. eradicating extreme poverty defined as living below the daily threshold of 1.25 USD (data valid for 2015), 2. at least halving the proportion of people living in poverty, 3. establishing appropriate universal social protection, 4. ensuring equal rights to economic resources, 5. enhancing the resilience of the poor and the vulnerable.
2	**Achieving food security, improved nutrition, and sustainable agriculture by eradicating hunger**: 1. safe, nutritious, and sufficient food, 2. ending malnutrition, 3. doubling productivity in agriculture and earnable incomes for small-scale food producers, 4. sustainable food production systems and resilient agricultural practices, 5. preserving the genetic diversity of both plants and animals by 2020.
3	**Health and well-being**: 1. improving maternal mortality, 2. paring down mortality for newborns and children under the age of 5 years, 3. abolishing specific diseases that can be transferred from one individual to another (e.g. tuberculosis or hepatitis), 4. cutting back premature mortality from non-communicable diseases by one-third, 5. mitigating substance abuse through enhanced prevention and treatment, 6. halving the number of deceased and injured persons due to road traffic accidents by 2020, 7. sexual and reproductive health care services, 8. universal health coverage, 9. moderating the number of deaths and illnesses caused by hazardous chemicals and environmental pollution.
4	**Inclusive and equitable quality education and lifelong learning**: 1. primary and secondary education with free access, 2. services before entering primary education, 3. affordable technical, vocational, and tertiary education, 4. more qualified youth and adults bearing relevant skills, 5. equal access to education and vocational training irrespective of socio-economic attributes, 6. improving literacy and numeracy rates by involving all youth and more adults, 7. transmitting knowledge and skills promoting sustainable development to all learners.
5	**Gender equality**: 1. stopping discrimination based on gender, 2. prevent violence against women and girls, 3. bringing harmful practices (e.g. corporal ones or those violating the principle of free marriages of persons at the legal age of maturity or above) to an end, 4. assigning a commensurate value to unpaid care and domestic work, 5. providing equal opportunities for leadership irrespective of gender, 6. health and rights in the field of sexuality and reproduction.

6	**Water and sanitation**: 1. safe and affordable drinking water, 2. adequate and equitable sanitation and hygiene, 3. improving water quality, 4. making substantial advancements in solving water scarcity, 5. integrated water resources management, 6. safeguarding water-related ecosystems by 2020.
7	**Clean and affordable energy**: 1. access to energy services, 2. building more on renewable energy sources worldwide, 3. improving energy efficiency at least by doubling its rate.
8	**Sustainable economic growth and decent work**: 1. realising country-specific GDP growth, 2. applying diversification, technological upgrading, and innovation to enhance economic productivity, 3. elaborating policies contributing to economic prosperity, 4. resource efficiency in both consumption and production, decoupling economic growth from its environmental impacts, 5. full employment and decent work by leaving no one behind, equal remuneration for the same work, 6. ensuring more opportunities in education, training, and employment for youth by 2020, 7. measures against forced labour, modern slavery, human trafficking, and child labour, 8. labour rights and safe and secure working environments, 9. policies supporting sustainable tourism, 10. widen the capacity of domestic financial institutions in offering their services.
9	**Sustainable infrastructure and industrialisation and fostering innovation**: 1. affordable and equitable access to an infrastructure promoting economic development and societal well-being, 2. inclusive and sustainable industrialisation with an augmenting share in both employment and GDP, 3. spread of small-scale enterprises by ameliorating their economic position and access to financial services, 4. rendering infrastructure and industries sustainable through resource-use efficiency and cleaner technologies and processes, 5. accelerating scientific research, stimulating innovation, and increasing the number of research and development (R&D) workers and the expenditure on R&D in the industry.
10	**Moderating national and international inequalities**: 1. ensuring a higher income growth to the lower 40% income group of the population, 2. universal social, economic, and political inclusion, 3. striving for equal treatment in the domain of legislation, policies, and practices, 4. greater equality through policies, 5. more stringent and profound regulation and monitoring of global financial markets, 6. more accentuated representation of the interests of developing countries in global economic and financial institutions, 7. ameliorating the migration and mobility framework.

11	**Inclusive and sustainable settlements**: 1. enabling appropriate housing and basic services to all, 2. safe transport systems with general access, more emphasis on public transport, 3. progress in sustainable urbanisation by involving more intensely citizens in settlement planning and management, 4. preserving cultural and natural heritage, 5. mitigating personal consequences and direct economic losses due to disasters, 6. lessening per capita environmental loads caused by cities, 7. offering green and public spaces.
12	**Sustainable consumption and production patterns**: 1. implementing the framework of related programmes by 2025, 2. rationalising the exploitation of natural resources through their sustainable management and efficient use, 3. halving per capita food waste globally and paring down food losses, 4. managing both chemicals and all wastes by minimising their harm to humans and the environment by 2020, 5. prioritising prevention, reduction, recycling, and reuse to generate less waste, 6. spread of sustainable corporate practices and reporting sustainability information, 7. sustainable public procurement, 8. providing information about and raising awareness for sustainable development around the globe.
13	**Tackling climate change**: 1. improving resilience against and adaptation to environmental hazards and disasters, 2. integrating actions against climate change when devising national policies and making strategies and plans, 3. mitigation, adaptation, and early warning related to climate change by means of education, heightening awareness, and widening capacity.
14	**Sustainable use of marine resources**: 1. substantially decreasing marine pollution by 2025, 2. making efforts to restore marine and coastal ecosystems to vital oceans by 2020, 3. eliminating ocean acidification, 4. restoring urgently fish stocks at least to levels enabling to harvest maximum sustainable yield through regulations to be laid down by 2020, 5. placing a minimum of 10% of coastal and marine areas under protection by 2020, 6. allowing only subsidies promoting sustainable fishing by 2020, 7. enabling least developed countries to realise more economic benefits from the sustainable use of marine resources.
15	**Sustainable use of terrestrial ecosystems**: 1. achieving the sustainable use of terrestrial and inland freshwater ecosystems and their services by 2020, 2. envisaging the sustainable management of forests by stopping deforestation and through restoration, afforestation, and reforestation by 2020, 3. striving to eliminate any kind of land degradation, including desertification, 4. conserving mountain ecosystems, 5. saving threatened species from extinction by 2020 and natural habitats from degradation, and preventing further loss in biodiversity, 6. distributing the benefits related to genetic resources in a fair, equitable, and accessible way, 7. halting illegal activities (e.g. poaching) affecting protected species, 8. launching measures addressing invasive alien species by 2020, 9. taking ecosystem and biodiversity values into consideration when deciding about plans, developments, strategies aiming at poverty reduction, and accounts by 2020.

16	**Peaceful and inclusive societies**: 1. curbing violence accompanied by dwindling death rates, 2. halting any kind of criminal acts against the dignity of children, 3. applying legal means within and between countries and enforcing equality in the access to jurisdiction, 4. restitution of stolen goods and actions against organised crime, illicit transactions targeting financial assets and arms, 5. taking effective anti-corruption and anti-bribery measures, 6. ensuring accountability and transparency of institutions and enhancing their effectiveness, 7. making decisions in accordance with the principles of modern democracies, 8. better representation of developing countries in intergovernmental organisations, 9. creating a legal identity from birth, 10. guaranteeing access to information and fundamental freedoms conforming with both domestic and international law.
17	**Global Partnership for Sustainable Development**: 1. developing the domestic state apparatus and its tools for collecting tax and other revenue more efficiently, 2. achieving the target related to official development assistance depending on the level of countries' development and commitments, 3. financial grants for developing countries, 4. rendering the long-term indebtedness of affected countries sustainable, 5. regimes promoting investments in favour of least developed countries, 6. supranational cooperation in order to deepen and improve the diffusion of science, technology, and innovation, 7. facilitating the development and transfer of environmentally sound technologies to the benefit of developing countries by applying preferential treatment, 8. setting up a technology bank and a system promoting the transmission and embeddedness of science, technology, and innovation in the circle of the least developed countries by 2017, in addition, contributing to the penetration of ICT and further enablers, 9. offering international support for developing countries in achieving each SDG through capacity-building, 10. reforming the multilateral trading system under the umbrella of the World Trade Organisation, including but not limited to the aftermath arising from its Doha Development Agenda, 11. augmenting the exports originating from developing countries by ensuring that the share of the least developed countries from global exports doubles by 2020, 12. removing trade barriers (duty and quota) on the imports from the least developed countries by applying transparent and simple preferential rules, 13. founding the world economy on such macroeconomic stability that is more resistant to shocks, 14. striving for the integrity of policies promoting sustainable development, 15. mutual respect of sovereignty between countries when devising and applying policies for sustainable development, 16. strengthening the global partnership by relying on a collaborative multi-stakeholder approach and common utilisation of immaterial and financial resources in order to accomplish SDGs, 17. exploiting the benefits extractable from partnerships amongst civil society and the public and private spheres, 18. enabling developing countries to have a better available, high-quality, timely, and reliable analytical data supply by 2020 through capacity-building, 19. developing tools apt for measuring the progress in achieving SDGs and their sub-dimensions and making advancements in collecting, producing, and providing statistics in developing countries.

25. Table: Milestones of global decarbonisation efforts and sustainable development in a nutshell (1972–2022)

Year	The event, its description, and the results achieved
1972	The first report of the Club of Rome (organisation unifying scientists and further prominent personalities) was published. The book titled 'The Limits to Growth' is a report of the findings of the researchers of the Massachusetts Institute of Technology reflecting on global issues. They pointed to the planetary limitations terminating former exponential growth perceived in the field of (i) population increase, (ii) agricultural and industrial output, (iii) depletion of non-renewable resources, (iv) pollution generation, and (v) their interactions. The alteration of the nature of growth is expected not to be avoided through advanced technological progress. Running more scenarios until 2100 confirmed the existence of states of global equilibrium between population and production provided that mankind imposes restrictions. (*Meadows et al., 1972, pp. 45-184*)
1972	The first world conference on the environment took place in Stockholm. One of the aims was to create the United Nations Environment Programme (UNEP), which induces, supports, and coordinates responses to environmental challenges. This event could be considered as the onset of global system-level discussions and negotiations between industrialised and developing countries targeting the triad of the environment, societies, and the economy. (*United Nations, 2023a, UNEP, 2023*)
1979	The First World Climate Conference convened in Geneva. They identified a grievous problem in climate change as a consequence of its effects on human activities. The experts appealed to nations to (i) investigate the mechanisms of climate and the adverse impacts of its variability and change on mankind, (ii) make advancements in gathering and sharing climate-related data, and (iii) consider the knowledge of climate when making decisions in a broad range of fields. (*WMO, 1979, pp. 3-6*)
1985	The Villach meeting hinted at the threat of anthropogenic climate change. (*ISC, 2018*)
1987	The World Commission on Environment and Development, chaired by Gro Harlem Brundtland, former Prime Minister of Norway, released its report titled 'Our Common Future'. The commission identified burning global problematic fields caused by (i) population increase, (ii) ensuring food security, (iii) extinction affecting ecosystems, (iv) energy use and supply, (v) industrial production, and (vi) urbanisation. It suggested a shift towards sustainable development as a lasting solution. The term 'sustainable development'[37] began its march around the globe. (*United Nations, 1987, pp. 1-9,*)
1988	The Intergovernmental Panel on Climate Change was created with the purpose of widening knowledge about climate change and investigating its impacts on societies and economies worldwide. Until 2023, the advisory organisation prepared the most comprehensive scientific reports of the field during five assessment cycles. (*IPCC, 2023*)
1988	The Toronto Conference on the Changing Atmosphere launched the reduction of CO_2 emissions with the participation of the largest economies and CO_2 emitters. It was designated to open negotiations in order to (i) lay down the global regulatory framework contributing to the stabilisation of the

[37] 'Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.' (*United Nations, 1987, p. 16*)

	concentrations of atmospheric GHGs by 1992, (ii) phase out fully-halogenated chlorofluorocarbons by 1995, (iii) achieve a 20% cut in emissions by 2000, and (iv) promote afforestation. (*WMO, 1989, p. 433*)
1990	The Second World Climate Conference in Geneva pointed to an at least 20% reduction opportunity in CO_2 emissions by 2005 by enhancing energy efficiency and using fuels and energy sources with less CO_2 intensity. (*UNFCCC, 1990, p. 5*)
1991	The document titled 'Caring for the Earth: A Strategy for Sustainable Living' could be considered as a toolkit composed of nine basic principles necessary for building practical strategies with the purpose of creating sustainable societies. (i) The founding ethical principle is respect and care for the community of life. (ii) Improving the quality of human life, (iii) conserving the Earth's vitality and diversity, (iv) minimising the depletion of non-renewable resources, (v) keeping growth within the Earth's carrying capacity, (vi) changing personal attitudes and practices, (vii) enabling communities to care for their environments, (viii) providing a national framework for integrating development and conservation, and (ix) creating a global alliance represent the values and duties indispensable for sustainable living. (*IUCN–UNEP–WWF, 1991, pp. 8-12*)
1992	The Earth Summit assembled in Rio de Janeiro on the 20th anniversary of the conference in Stockholm in order to agree on the blueprint for how to address environmental and development issues in the next decades. The negotiations amongst the participants culminated in (i) the United Nations Framework Convention on Climate Change, (ii) the Rio Declaration, (iii) Agenda 21, (iv) the Convention on Biological Diversity, and (v) the Declaration on the Principles of forest management. (*United Nations, 2023b*)
1995	The report called 'Factor Four: Doubling Wealth, Halving Resource Use' was published to the Club of Rome in 1995. It rests on the concept that radical bettering may double welfare while it halves resource consumption and environmental load. Thus, this fourfold improvement in resource productivity bears the potential to resolve the unsustainable scenarios modelled in 'The Limits to Growth' (1972). (*BCIT, 2023*)
1997	The scope of the Kyoto Protocol was partial by involving a limited circle of emitters. It covered only 18% of global GHG emissions and 37 industrialised countries by imposing emission reduction targets or caps. Under the auspices of this legally binding agreement, participating countries set formal reduction targets by an average of 5% below the base year levels of 1990, while the pledges of EU-15 as a whole amounted to an 8% cut for the first commitment period (2008–2012). After the ratification of the Doha Amendment (2012), the Protocol was extended to 2020 with the participation of more countries and a widened scope. During the entire second period (2013–2020), EU countries committed themselves to a joint 20% decrease by applying the same initial point represented by 1990. (*EC, 2023b, 2023c*)
2000	The Millennium Summit held in New York introduced a new development strategy by setting eight Millennium Development Goals to be achieved by 2015 with a particular focus on the world's poorest and people in vulnerable situations. The fields encompassed were (i) extreme poverty and hunger, (ii) primary education, (iii) gender equality, (iv) child mortality, (v) maternal health, (vi) diseases, (vii) environmental sustainability, and (viii) global partnership for development. (*United Nations, 2023c*)

2002	The World Summit on Sustainable Development organised in Johannesburg could be considered – in addition to novel achievements – as a continuation of making progress in the Millennium Development Goals and regarding the Kyoto Protocol. The chapters of negotiations affected (i) water resources, (ii) energy supply (e.g. adding renewable energy sources), (iii) the fight against diseases and access to medicines, (iv) agriculture, (v) use of genetic resources, (vi) solidarity fund for the eradication of poverty, and (vii) sustainable production and consumption patterns. (*United Nations, 2023d*)
2005	A new era began when the Kyoto Protocol – setting up a global carbon market – entered into force and the United Nations Climate Change Conference in Montreal fully implemented and improved the emissions trading, the Joint Implementation (the case where an industrialised country invests in another developed country), and Clean Development Mechanism (investing in developing countries to promote sustainable development) under the Kyoto Protocol. (*UNFCCC, 2005, p. 1*) The EU Emissions Trading System (ETS) was launched in 2005 by having recourse to national allocation plans resting on nationally set caps on allowances (1 allowance equals one tonne of carbon dioxide equivalent). The aim of the first phase (2005–2007) was to mould the effective functioning of the EU for the second phase (2008–2012) so that the EU could meet its Kyoto targets. The initial 3-year pilot period of the world's first international emissions trading system involved only CO_2 emissions arising from energy supply and energy-intensive industries. Caps were determined based on estimates. The free allocation of allowances exceeding emissions under the scope resulted in a zero price in 2007. The introduction of a penalty amounting to €40 per tonne to be applied in the case of non-compliance was symbolic. Despite this market failure, the EU succeeded in establishing a carbon price, the free trade of allowances across the EU, and the required infrastructure. The second phase (2008–2012) of the largest carbon market of the world utilised a 6.5% reduction in the overall cap on allowances, the scope widened after the adhesion of Iceland, Liechtenstein, and Norway, and was expanded to a part of dinitrogen oxide emissions and the aviation sector except for flights to and from non-European countries (the latter took place in 2012). Furthermore, an approximately 90% free allocation, making use of auctions, a higher penalty of €100 per tonne, and the possibility to buy international credits characterised this interval. The third phase (2013–2020) replaced national caps with a single, EU-wide cap subject to a 1.74% yearly cut for stationary installations and auctioning took the place of the formerly by default applied free allocation of allowances. In addition, it introduced harmonised allocation rules related to free allowances; covered more sectors and GHGs, and set up the NER 300 programme (300 million allowances dedicated to the New Entrants Reserve) to fund the spread of innovative, renewable energy technologies and carbon capture and storage. In 2019, the launch of the Market Stability Reserve stabilised carbon prices at a higher level. The fourth phase (2021–2030) applies a more stringent annual linear reduction factor of 2.2% for stationary installations. Due to mandatory participation and continuous regulation, the combinations of affected GHGs (CO_2, N_2O, and perfluorocarbons) and involved sectors incorporate currently almost 10 thousand companies responsible for nearly 40% of the EU's GHG emissions. Setting up the Innovation Fund and the Modernisation Fund are further steps to promote the transition to a low-carbon economy. (*EC, 2023d-2023f*)

2009	The United Nations Climate Change Conference held in Copenhagen ended up agreeing on the Copenhagen Accord, which envisaged setting limitations to the global average temperature rise and raising funds with the purpose of both climate adaptation and mitigation to the benefit of developing countries. (*EEA, 2016*)
2010	The world's leaders gathered at the United Nations climate conference in Cancún to make a noticeable step on the climate pathway. The Cancún Agreements carried forward and reinforced the Copenhagen Accord by relying on the tools of adaptation and mitigation, providing financial (e.g. through the Green Climate Fund), technology, and capacity-building support to enable developing countries to tackle climate change. (*UNFCCC, 2023a*)
2011	The focus of the United Nations Climate Change Conference in Durban could be encapsulated in four main areas: (i) prolonging the Kyoto Protocol with a second commitment period, (ii) launching a new platform of negotiations for an effective, legally binding, new global climate change agreement by 2015 with the wish of addressing climate change beyond 2020, (iii) terminating within 2012 the negotiations targeting more transparent national emission reduction or limitation plans and creating a global support network providing funding and technology in order to turn societies and economies more resilient to climate change with particular attention to developing countries, (iv) carrying out a global review concerning the required limit (2 or even a more ambitious 1.5 degrees above the pre-industrial levels) to master the climate challenge. (*UNFCCC, 2023b*)
2012	The pivot of the United Nations Climate Change Conference in Doha was to give the green light to the implementation of achievements of previous conferences. The package of documents titled 'Doha Climate Gateway' referred inter alia to an eight-year extension of the Kyoto Protocol and an agreement about the loss and damage mechanism envisaging compensating financially climate-vulnerable developing countries in the future by countries not meeting their emission reduction commitments. (*IISD, 2023a*)
2013	The United Nations Climate Change Conference in Warsaw anticipated the Paris Agreement (which will be entering into force in 2020) to be concluded by the end of 2015. (i) In line with it, an appeal for taking preparatory measures concerning nationally determined contributions was announced so that the reduction in emissions could be accelerated and expanded with joint forces. (ii) In addition to mitigation, the gathering alluded to the need for enhanced adaptation capacity. The Warsaw Framework for REDD+ (the abbreviation stands for reducing emissions from deforestation and forest degradation) set out to bolster forest preservation and protection as well as halt deforestation and forest degradation. (iii) In order to support the actions of developing countries, first, the parties envisaged capitalising the Green Climate Fund (a financial tool) in the second half of 2014, second, the Climate Technology Centre and Network started its operation to promote technology cooperation and transfer, third, the least developed countries rounded off their plans enhancing resilience. (iv) Further topics were narrowing the gap between current pledges and the 2-degree requirements, the Warsaw International Mechanism for Loss and Damage, mobilising annually 100 billion USD by industrialised states until 2020 and improving accountability through better measurement of efforts. (*UNFCCC, 2023c*)

2014	The United Nations Climate Change Conference in Lima was the last principal stage prior to the Paris Agreement. The (i) promising pledges (min. 40% drop in GHG emissions proposed by the EU, participation and commitments of the United States and China), (ii) transparency, (iii) quantifiability, and (iv) comparability of the reduction targets, as well as (v) their analysis in terms of ambition and adequacy were decent signs of global collective intention to deal with climate change commensurately with its importance. Nonetheless, further negotiations were required in 2015 to finalise the 2015 Agreement and achieving more ambitious mitigation before 2020 remained on the agenda. (*EC, 2023g*)
2015	The 2030 Agenda for Sustainable Development was agreed upon in New York (for more details regarding SDGs and their targets, see Table 24 of the Appendix). (*United Nations, 2015, pp. 1, 3*)
2015	The Paris Agreement effectively replaced the Kyoto Protocol. The legally binding international treaty was adopted on 12 December 2015 but it has been in force since 4 November 2016. Compared to pre-industrial levels, the increase in the global average temperature must remain well below 2°C. In addition, a more ambitious desired goal was set through the threshold of 1.5°C. To plan the roadmaps to reach carbon neutrality, countries laid down their nationally determined contributions subject to future amendments. (*UNFCCC, 2023d*)
2016	The United Nations Climate Change Conference in Marrakesh was a direct sequel to previous gatherings. Amongst others, it addressed issues related to the Green Climate Fund and the Global Environment Facility by providing guidance, endeavoured to accelerate climate technology development and transfer through the Technology Mechanism, and contributed to the entry into force of the Paris Agreement. (*IISD, 2023b*)
2019	By announcing the European Green Deal, the EU stipulated its intention to achieve climate neutrality (net-zero emissions[38]) by 2050 and decouple economic growth from resource use by safeguarding the competitiveness of the economy. (*EC, 2019, p. 2*)
2021	In accordance with the European Green Deal, the EU accepted legislative proposals (including the review of EU ETS) with the purpose of designating its climate pathway by 2050. As a corollary of this package, the net reduction in GHG emissions was projected to achieve at least 55% by 2030 compared to 1990. (*EC, 2023d, 2023f*)
2022	The international environmental meeting Stockholm+50 steered the attention to the waning remaining time to achieve the 2030 Agenda for Sustainable Development by inserting green recovery plans after the COVID-19 pandemic as a mid-step, relying on the post-2020 global biodiversity framework, and progressing in the abatement of GHG emissions concordant with the Paris Agreement.[39] (*Stockholm+50, 2023*)

[38] A net-zero economy means that anthropogenic GHG flows to and from the atmosphere are balanced at the aggregate level (e.g. by means of less consumption of fossil fuels, reducing carbon emissions arising from land use, and removal through geological and biological sinks), i.e. the cumulative flows equal zero. (*Fankhauser et al., 2022, p. 16*)

[39] In 2019, the share of renewable energy sources within global final energy consumption amounted to 17.7% if biomass is included, while it moderates to 11.5% when discarding biomass. Albeit being on track with the climate objective of the Paris Agreement would necessitate an analogous share of renewable energy sources without biomass of 32% by 2030, the current projection points to 18% by 2030. (*IEA, 2023c)*

26. Table: Collinearity statistics for the linear regression models (fourth article)
Coefficient of multiple determination (R^2_j), tolerance (Tol), variance inflating factor (VIF), condition index, variance proportion, and Pearson correlation (*Kovács, 2014, pp. 89-90, 93-95)*

	Including H1 and H3			Without H1 and H3		
Variable	R^2_j (%)	Tol	VIF	R^2_j (%)	Tol	VIF
S1	16.87	0.831	1.203	10.40	0.896	1.116
S2	22.34	0.777	1.288	22.07	0.779	1.283
S3	15.84	0.842	1.188	15.63	0.844	1.185
age_2019	19.88	0.801	1.248	18.77	0.812	1.231
S5	3.05	0.969	1.031	2.54	0.975	1.026
S6	27.80	0.722	1.385	7.86	0.921	1.085
S8	21.26	0.787	1.270	14.66	0.853	1.172
H12B	14.67	0.853	1.172	14.38	0.856	1.168
AGR_NEG_STAT	14.17	0.858	1.165	13.73	0.863	1.159
AGR_INCONV_EFM	11.69	0.883	1.132	11.49	0.885	1.130
H1	41.64	0.584	1.714			
H3	38.56	0.614	1.628			
H13A	14.05	0.860	1.163	12.62	0.874	1.144

Dimen-sion	Eigen-value	Condi-tion index	Variance proportions													
			(Con-stant)	S1	S2	S3	age_ 2019	S5	S6	S8	H12B	AGR_ NEG_ STAT	AGR_ INC ONV_ EFM	H1	H3	H13A
1	12.276	1.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.396	5.568	0.00	0.06	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.17	0.05	0.00
3	0.327	6.129	0.00	0.08	0.00	0.49	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.06	0.00	0.00
4	0.224	7.409	0.00	0.06	0.01	0.06	0.00	0.00	0.03	0.04	0.39	0.00	0.00	0.03	0.05	0.00
5	0.178	8.298	0.00	0.51	0.01	0.24	0.04	0.01	0.04	0.02	0.04	0.00	0.00	0.00	0.04	0.00
6	0.144	9.232	0.00	0.00	0.00	0.02	0.01	0.01	0.11	0.27	0.41	0.00	0.00	0.01	0.08	0.00
7	0.099	11.136	0.00	0.02	0.00	0.02	0.02	0.02	0.58	0.29	0.00	0.00	0.02	0.13	0.07	0.00
8	0.097	11.268	0.00	0.01	0.00	0.00	0.05	0.79	0.04	0.00	0.01	0.01	0.01	0.05	0.01	0.00
9	0.072	13.034	0.00	0.18	0.00	0.08	0.63	0.06	0.02	0.04	0.02	0.00	0.02	0.08	0.24	0.00
10	0.063	13.948	0.00	0.01	0.00	0.01	0.09	0.01	0.03	0.23	0.02	0.18	0.26	0.14	0.15	0.00
11	0.044	16.758	0.00	0.02	0.09	0.01	0.02	0.03	0.04	0.03	0.00	0.10	0.03	0.14	0.05	0.56
12	0.039	17.818	0.00	0.00	0.35	0.01	0.00	0.02	0.01	0.00	0.08	0.09	0.03	0.07	0.15	0.30
13	0.037	18.275	0.00	0.03	0.06	0.00	0.06	0.01	0.00	0.03	0.00	0.50	0.59	0.02	0.00	0.01
14	0.005	49.521	0.99	0.02	0.49	0.02	0.06	0.04	0.03	0.04	0.02	0.11	0.03	0.10	0.10	0.12

Without H1 and H3: The maximum of the condition index is 43.215.

Pearson correlations	S2	S3	age_ 2019	S5	S6	S8	H12B	AGR_ NEG_ STAT	AGR_ INC ONV_ EFM	H1	H3	H13A
S1	.047**	-.092**	-.273**	-.046**	.066**	0.013	.041**	0.003	-0.011	-.158**	.209**	.048**
S2	1	-.227**	-.209**	0.000	-.195**	-.239**	-.197**	-.222**	-.123**	.076**	.047**	-.197**
S3		1	.249**	.127**	.050**	.142**	0.016	0.022	0.024	-0.014	-.037*	0.018
age_2019			1	-0.012	.128**	.049**	.074**	.123**	0.023	-.061**	.054**	.055**
S5				1	-0.025	.073**	0.022	-.062**	-0.025	.052**	-.056**	-0.010
S6					1	.084**	.098**	.122**	.056**	-.460**	.243**	.126**
S8						1	.189**	.092**	.200**	0.009	-.305**	.207**
H12B							1	.164**	.074**	-.056**	-.119**	.178**
AGR_NEG_STAT								1	.281**	-0.026	-0.020	.111**
AGR_INCONV_EFM									1	-.047**	-0.019	.080**
H1										1	-.446**	0.011
H3											1	-.133**

** Correlation is significant at the 1% level (2-tailed). * Correlation is significant at the 5% level (2-tailed).

27. Table: Collinearity statistics for the linear regression models (fifth article)
Coefficient of multiple determination (R^2_j), tolerance (Tol), and variance inflating factor (VIF)[40] (*Kovács, 2014, pp. 93-95)*

Countries involved in the final model	Merged (HU, NO, PL)			Hungary			Norway		
Initial set of independent variables	33			33			32		
Number of regressors in the final model	8			6			5		
Final sample size	585			364			86		
R square (%)	39.39			41.25			50.66		
Adjusted R square (%)	38.55			40.27			47.57		
Variable	R^2_j (%)	Tol	VIF	R^2_j (%)	Tol	VIF	R^2_j (%)	Tol	VIF
Zscore(NUM_FOUR_ WHEEL_TRAD_VEH)	10.45	0.896	1.117	4.01	0.960	1.042	31.37	0.686	1.457
Zscore(M5_cost)	21.77	0.782	1.278	24.95	0.750	1.332			
Zscore(M5_flexibility)	19.77	0.802	1.246	16.52	0.835	1.198			
Zscore(SCORE_ TRANS_SYS)	12.08	0.879	1.137				9.32	0.907	1.103
Zscore(SATIS_TRANS)	2.54	0.975	1.026						
Zscore(LESS_ ENERGY_CONS)	2.78	0.972	1.029						
Zscore(S3-employment status)	10.06	0.899	1.112						
Zscore(S5-gender)	2.13	0.979	1.022	2.88	0.971	1.030			
Zscore(AGR_NEG_ STAT)				5.91	0.941	1.063			
Zscore(M5_CO2_ emissions)				14.62	0.854	1.171			
Zscore(M5_availability)							16.60	0.834	1.199
Zscore(M5_time)							17.73	0.823	1.216
Zscore(S6-type of residence area)							25.47	0.745	1.342

(Table continues on the next page.)

[40] Condition indices and variance proportions are not disclosed here. The presence of multicollinearity was controlled based on the condition index as well. None of the condition indices exceeded 5, i.e. the ceiling referring to tolerable weak multicollinearity. For more details see the fifth article, section Data analysis.

(Continued.)

Countries involved in the final model	Poland			Italy			Spain		
Initial set of independent variables			33			28			28
Number of regressors in the final model			8			7			7
Final sample size			149			406			242
R square (%)			55.54			24.69			39.99
Adjusted R square (%)			53.00			23.37			38.20
Variable	R^2_j (%)	Tol	VIF	R^2_j (%)	Tol	VIF	R^2_j (%)	Tol	VIF
Zscore(NUM_FOUR_ WHEEL_TRAD_VEH)	14.9	0.851	1.176	33.09	0.669	1.495	7.77	0.922	1.084
Zscore(M5_flexibility)	29.87	0.701	1.426						
Zscore(SCORE_ TRANS_SYS)	17.20	0.828	1.208				16.49	0.835	1.197
Zscore(LESS_ ENERGY_CONS)	14.27	0.857	1.166						
Zscore(S3-employment status)	17.37	0.826	1.210	3.06	0.969	1.032	6.86	0.931	1.074
Zscore(AGR_NEG_ STAT)				3.36	0.966	1.035			
Zscore(M5_availability)				4.17	0.958	1.043			
Zscore(M5_time)	28.97	0.710	1.408						
Zscore(S6-type of residence area)							25.95	0.741	1.350
Zscore(SEV_TRAF_ PROB)	28.28	0.717	1.394				32.23	0.678	1.476
Zscore(ASSESS_ INFRASTR)	7.48	0.925	1.081						
Zscore(NUM_TWO_ WHEEL_TRAD_VEH)				12.00	0.880	1.136			
Zscore(NUM_FOUR_ WHEEL_ELEC_VEH)				24.13	0.759	1.318			
Zscore(age_2019)				5.44	0.946	1.058			
Zscore(M5_reputation)							10.58	0.894	1.118
Zscore(S8-subjective evaluation of house-hold's current income)							7.81	0.922	1.085

12. Relevant publications of the author

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