Carolina Machado
João Paulo Davim *Editors*

Corporate Governance for Climate Transition

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Preface

Climate change is a reality today. In addition to the profound environmental challenges that these changes imply, organizations are not exempt from the transformations that result from them. In effect, these changes in the climate are having a strong impact on organizations, affecting many of their businesses. Even at the level of strategies, policies and practices, as well as technologies/tools, developed to face these transformations, there are many challenges and constraints generated in organizations. If, on the one hand, a wide range of risks can be observed, on the other hand, there are also many opportunities that may arise. An example of the resulting implications are the efforts that have been made in this area, particularly following the Paris Agreement and, more recently, the contributions resulting from the Special Report of the Intergovernmental Panel on Climate Change in relation to global warming 1.5 ºC (IPCC). In this context, alerted to this reality, the organizational leaders, together with the different internal and external stakeholders, have been developing a set of strategies, policies and organizational practices in order to respond efficiently and effectively to the challenges, risks and opportunities resulting from the climate change.

If it is true that the climate changes that are increasingly being observed exert a strong pressure (sometimes positive, sometimes negative) on organizations, forcing government and decision-making bodies to intervene effectively, also the different decisions and respective actions developed by the companies, will have a strong impact on the environment, contributing considerably to the climatic changes that are being observed (either in a positive perspective or in a negative perspective). In short, the interaction that is felt here presupposes, on the part of these organizational leaders, the definition and implementation of strategies and policies compatible with the necessary levels of competitive and sustainable performance.

Aware of this reality, this book entitled *Corporate Governance for Climate Transition* aims to contribute to a better understanding of the impacts that climate transition that we are experiencing has on organizations, and the way that these, in the figure of their key decision-makers, are organizing themselves to reinforce opportunities while simultaneously overcoming the underlying risks. What corporate governance models

can and are organizations developing? What climate transition strategies are organizations outlining? Which actors are or should be involved in the decision-making processes? To what extent are principles of transparency, equity, participation, inclusion, effectiveness and efficiency present in corporate governance for climate transitions? These and other issues are just a few of the challenges that organizations are facing in a context of great transitions such as the one we are currently experiencing.

Organized in nine chapters, *Corporate Governance for Climate Transition* looks to discuss in Chapter 1 "*The Future of Corporate Purpose: Merging and Balancing Social, Environmental and Economic Considerations*"; while Chapter 2 speaks about "*Identifying Significant Shifts in Operating Environments: The Role of Corporate Governance*". Chapter 3 deals with "*Governance Principles for Sustainable Urban Tourism and Climate Transition*"; Chapter 4 focuses on "*Analysis and Forecasting of Water Resources and Use in the Context of Climate Transition in Selected EU Countries*"*; and* Chapter 5 presents "*An Introduction to the Use of Life Cycle Assessment in Machining*". Chapter 6 deals with "*Corporate Social Responsibility and Environmental Performance: Reporting Initiatives of Oil and Gas Companies in Central and Eastern Europe*", while Chapter 7 focuses "*'Do No Significant Harm' Principle and Current Challenges for the EU Taxonomy Towards Energy Transition*". Chapter 8 covers "*Agroecology, Service-Learning, and Social Responsibility: A Case Study for Spain*", and finally, Chapter 9 deals with "*Performance Appraisal Systems for the Evolution of Environmental Competencies: Achieving Goals and Rewards*".

Corporate Governance for Climate Transition can be used by a variety of potential stakeholders, including academics/researchers, managers, engineers, practitioners and other professionals in the different areas of business and management. A very special target audience consists of students from different undergraduate/graduate levels (undergraduate, masters and doctoral/Ph.Ds.), from the areas of management and industrial engineering, for which this book constitutes a fundamental support capable of providing a focused and current view about the key challenges, trends, implications, strategies and ways of overcoming, that dynamic and competitive organizations are facing today and increasingly in the near future.

The Editors acknowledge their gratitude to Springer for this opportunity and for their professional support. Finally, we would like to thank to all chapter authors for their interest and availability to work on this project.

Braga, Portugal — Carolina Machado
Aveiro, Portugal — João Paulo Davim

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About the Editors

Carolina Machado received her Ph.D. degree in Management Sciences (Organizational and Politics Management area/Human Resources Management) from the University of Minho in 1999, Master degree in Management (Strategic Human Resource Management) from Technical University of Lisbon in 1994 and Degree in Business Administration from University of Minho in 1989. Teaching in the Human Resources Management subjects since 1989 at University of Minho, she is since 2004 Associate Professor (with Habilitation since May 2022), with experience and research interest areas in the field of Human Resource Management, International Human Resource Management, Human Resource Management in SMEs, Training and Development, Emotional Intelligence, Management Change, Knowledge Management and Management/HRM in the Digital Age/Business Analytics. She is Head of the Human Resources Management Work Group at the School of Economics and Management at University of Minho, Coordinator of Advanced Training Courses at the Interdisciplinary Centre of Social Sciences, Member of the Interdisciplinary Centre of Social Sciences (CICS.NOVA.UMinho), University of Minho, as well as Chief Editor of the *International Journal of Applied Management Sciences and Engineering* (IJAMSE), Guest Editor of journals, books Editor and book Series Editor, as well as reviewer in different international prestigious journals. In addition, she has also published both as editor/co-editor and as author/co-author several books, book chapters and articles in journals and conferences.

João Paulo Davim is a Full Professor at the University of Aveiro, Portugal. He is also distinguished as honorary professor in several universities/colleges/institutes in China, India and Spain. He received his Ph.D. degree in Mechanical Engineering in 1997, M.Sc. degree in Mechanical Engineering (materials and manufacturing processes) in 1991, Mechanical Engineering degree (5 years) in 1986, from the University of Porto (FEUP), the Aggregate title (Full Habilitation) from the University of Coimbra in 2005 and the D.Sc. (Higher Doctorate) from London Metropolitan

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The Future of Corporate Purpose: Merging and Balancing Social, Environmental and Economic Considerations

Stelios Andreadakis

Abstract The present chapter deals with the social enterprises' landscape in the United Kingdom, with emphasis on Certified B Corps, Benefit Corporations and Community Interest Companies (CIC). Although the UK has the reputation of a jurisdiction that supports the shareholder value theory and the shareholder maximisation paradigm, it has introduced special rules for social enterprises and has facilitated the development of Benefit Corporations and B Corps. The UK experience may be significantly different from the United States' one, but it can operate as an example to follow for countries that aim at becoming more inclusive in terms of corporate social responsibility and social purpose.

Keywords B-Corps · CSR · Corporate purpose · CIC · Social enterprises

1 Introduction

During the past two decades, the newspaper headlines and the media have been flooded by stories of corporate scandals and misdeeds, such as Enron, WorldCom, Tyco, Adelphia, Parmalat, Satyam Computer Services, Lehman Brothers, AIG, Massey, Olympus, and MF Global. The impact of these scandals on the stability and the reputation of the global financial markets was tremendously negative and has led governments and the business community to revisit the concept of the traditional corporation. In the context of the required transformation of the corporate purpose, reference has been made to numerous terms, such as social enterprises[1] (Borzaga et al., 2009; Boschee et al., 2010, p. 1), social purpose, public interest and blended value (Bugg-Levine & Emerson, 2011, pp. 10–11). As a result, both the

[1] The term 'social enterprise' refers to public benefit organisations that pursue the satisfaction of social needs through the imposition of at least a partial non-profit constraint and by devoting the majority of their positive residuals and patrimony to socially oriented activities. In the United States, the term has a broader meaning and social enterprise are those using traditional business

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US and several European Union (EU) Member States have introduced special legal frameworks for social enterprises.

According to the European Commission, the social economy is dynamic and constantly growing. It employs more than 14.5 million people in the EU, corresponding to 6.5% of the active workforce (European Commission, 2013, p. 45). The development of the social economy is not only seen in the EU but also globally, not least in the US, where there has been a wave of initiatives to promote social enterprises (Defourny & Nyssens, 2008, p. 4). The solutions range from amendments to the existing company legislation through to certification schemes and to new corporate forms, such as benefit corporations, community interest corporations (CIC), limited liability companies (L3C), benefit limited liability companies (BLLC), flexible purpose corporations (FPC), social purpose corporations (SPC) and, last but not least, the Certified B Corporations. All these initiatives reflect a fundamental change to the traditional business model implemented in both sides of the Atlantic Ocean and are all part of a movement towards greater transparency and commitment to pursuing social and environmental objectives in addition to profits.

The present chapter will focus on the social enterprises' landscape in the United Kingdom, with emphasis on Certified B Corps, Benefit Corporations and the CICs. Section 2 discusses the background to the introduction of special rules for social enterprises. This is followed by Sect. 3, where an overview of the Benefit Corporations and B Corps will be provided using evidence for the United States and the UK. Section 4 looks at the formation and the operation of CICs and an attempt is made to reflect on the experience from their operation in the UK so far. Section 5 puts the previously discussed initiatives in the context of the wider debate about sustainability and a more inclusive corporate purpose. Section 6 contains the concluding remarks of the chapter.

2 The Shift Towards Social Enterprises

Before we discuss the gradual, but steady, shift towards social enterprises and delve into the regulatory framework currently in place in the UK, it is essential to offer an overview of this concept and its basic characteristics. Social enterprise is defined as 'the use of market-based strategies to promote the public good' (Cummings, 2012, p. 578). Another commonly used definition provides that it is 'an organisation or venture that achieves its primary social or environmental mission using business methods, typically by operating a revenue-generating business' (Katz & Page, 2010, p. 85). As it becomes apparent from these definitions, the main feature of social enterprises is that they combine the performance of a commercial activity with a

methods to accomplish charitable or socially beneficial objectives or companies with a significant mission-driven motive, regardless of whether profit is the primary objective. There are also narrower definitions put forward, according to which social enterprises must directly address social needs through their products and services or through the numbers of disadvantaged people they employ.

social one and there is no exclusive emphasis on profit-maximisation. The European Commission has defined a social enterprise as 'an operator in the social economy whose main objective is to have a social impact rather than make a profit for their owners or shareholders' (European Commission, 2011, p. 2). This definition signals that it concerns companies that have a social agenda and demonstrate a commitment to act as a responsible actor at international level for the realisation of this agenda's goals. Social enterprises are expected not only to give priority to social considerations than profits, but to actually use part of their profits for social purposes. Thus, it needs to be underlined that social enterprises have gone through a reconceptualisation of their business model, while looking for their own cosmotheory and system of values (Delbard, 2020).

A careful consideration of the current status quo in the UK reveals we are still far away from being able to talk about a social economy and stakeholder-focused businesses. In fact, company directors, guided by a commercial and legal system that was designed to prioritise shareholder welfare, never had any strong incentives to consider pursuing any other purpose (Bebchuk & Tallarita, 2020; Millon, 2010). This idea, known as the principle of shareholder primacy, came to prominence in the US and UK throughout the nineteenth and twentieth century on the basis that maximising shareholder returns would maximise total social welfare, and that corporate resources should be diverted toward social goods, such as environmental welfare. Although not explicitly enshrined in statute, a substantial body of case law has held that the interests of a company are the interests of its shareholders and that company resources could not be diverted for any purpose that would not benefit them. Milton Friedman has been famously quoted as a justification for the prevalence of a sheer profit-maximisation corporate paradigm and it has become a slogan that the 'There is one and only one social responsibility of business—to use its resources and engage in activities designed to increase its profits' (Friedman, 1970), same as the judgement in *Dodge v Ford*, where it was stated that 'a business corporation is organized and carried on primarily for the profit of the stockholders. The powers of the directors are to be employed for that end. The discretion of directors is to be exercised in the choice of means to attain that end, and does not extend to a change in the end itself, to the reduction of profits, or to the non-distribution of profits among stockholders in order to devote them to other purposes…' (para 684). There have been several other quotes that could have been used for slogans, such as Henry Ford's statement that, instead of boosting dividends, he would rather use the money to build better cars and pay better wages or Johnson & Johnson's credo, written by General Robert Wood Johnson in 1943, that the company's first responsibility was not to investors but to doctors, nurses, and patients, but shareholder primacy was so deeply embedded in the Anglo-Saxon corporate world that it was extremely difficult to deviate from it (Johnson & Johnson, 1943).

The late twentieth century saw a relaxation of this position, which was accompanied by greater corporate involvement in the wider community through corporate social responsibility (CSR) initiatives. The introduction of the UK Companies Act 2006 and the adoption of the Enlightened Shareholder Value theory through section 172 was hailed as the end of short-termism and the beginning of a new era in

corporate behaviour. We have to accept that section 172 did not bring the expected change of culture in corporate boardrooms and it has been argued that it has not lived up the expectations and in effect shareholder primacy remains at the core of the UK company law system (Collison et al., 2011, p. 44; Fettiplace & Addis, 2010 pp. 61–62). However, it became apparent that blind short-termism can only have a negative effect on modern corporations and stakeholders' interests should not be ignored or overlooked in favour of those of shareholders.

Having regard to the interests of stakeholders is not a legally enforceable duty and falls short in disincentivising any investment that would detract from profit maximisation; nevertheless, companies can no longer afford to be disengaged from the society within which they operate, ignoring their social responsibilities. The 2007–2009 financial crisis has highlighted this need to focus on the responsibilities, including social ones, of companies, investors, consumers and public authorities in relation to the challenges of climate change, the limits to natural resources and respect for human rights (Taylor, 2009/2010, p. 743). There is no expectation that companies solve the problems that our society experiences on their own, while at the same time are struggling to remain competitive and profitable. The market though will react positively to the fact that a company is actively seeking to be socially responsible and sustainable (Zrilic, 2012). For instance, it can give companies a competitive advantage in attracting new investors and trading partners, while it will boost sales and increase customer loyalty. At the same time, socially responsible companies can attract better qualified staff, who share the same values and aspirations, and increase the productivity and commitment of their existing employees, who will feel that they are being part of a larger cause (von Arx & Zeigler, 2008).

Without strong and clear incentives, it is hard for companies to initiate a radical transformation of their business operations; not only the costs associated with this transition are likely to be high, but also without legal enforcement companies are unlikely to be convinced to take the risk, especially during the current times of uncertainty (British Property Federation, Spada, & Taylor Wessing, 2010). As Liao notes, it is the board of directors, who should step up and be the drivers for change (Liao, 2015, p. 318). At the same time, it would be hard for directors to justify the need for changes and even implement them without any sort of legal framework, which will operate as a rough roadmap. This is why there have been introduced provisions allowing companies to adopt a legal structure that deviates from the traditional shareholder value paradigm and expands the corporate purpose beyond the narrow limits of the pecuniary interests of its shareholders (Attenborough, 2022). The next section will examine two of the most popular initiatives that have attracted the attention of entrepreneurs and serve as evidence that a shift towards more pluralistic corporate forms is actually taking place.

3 Benefit Corporations and B Corps

Starting with the Benefit Corporation (Hemphill & Cullari, 2014), this is a legal structure for a business, which exists in several countries across the globe, including the USA, Italy and Colombia. In the US, the 'benefit corporation' form was introduced in 2010 and so far it has been adopted in 38 states as well as the District of Columbia, while more than 40 state jurisdictions across the country have enacted at least one social enterprise statute. It is designed for 'for profit' undertakings that also wish to take account of social and environmental considerations (Blount & Offei-Danso, 2013). Their purpose must be to 'create general public benefit', which is defined as having 'a material positive impact on society and the environment'. There is no obligation to reinvest profits, nor are there limits to the distribution of profits, as the legal requirement for creating a 'general public benefit' can be met through the normal operation of the company, by having regard to its stakeholders and trying to combine profit maximisation with positive stakeholder impact (Clark Jr & Vranka, 2013).

From a first glance, it seems that there are similarities with the enlightened shareholder value theory that the UK government has tried to implement through section 172 of the Companies Act 2006 (CA 2006). Actually, one could not help wondering whether the benefit corporations has been another attempt to deviate from the shareholder value paradigm with an element of flexibility, considering that the adoption of this corporate vehicle is optional. Although there is no evidence that the introduction of the rules regarding the benefit corporation has any connection with ESV, it can still be argued that the swift towards a different type of corporations and a more pluralistic mode of governance is gradually becoming a reality. Is this the result of a process of enlightenment or just of the pressure exercised by the market and stakeholder groups? It doesn't really matter, because the two main supporters of shareholder primacy, the US and the UK, have been actively exploring different options. What is also extremely important is that these options have the potential to introduce a different culture in the boardrooms and ultimately to drive corporate management away from short-termism towards a more long-run perspective.

Benefit Corporations are often confused with Certified B Corporations. The main difference is that B Corp is a certification, while benefit corporation is a legal form. The B Corp Certification of social and environmental performance is a third-party certification administered by the non-profit B Lab, based in part on a company's verified performance on the B Impact Assessment. B Lab was founded in 2006 by Stanford University alumni and businessmen Jay Coen Gilbert and Bart Houlahan, and former investment banker and Stanford colleague, Andrew Kassoy. The companies that have obtained this certification can designate themselves as 'Certified B Corporations'. Some companies are both Certified B Corporations and benefit corporations, and the Benefit Corporation as a corporate structure fulfils the legal accountability requirement of B Corp Certification. The certification is a *prima facie* indication for

a company's environmental performance, employee relationships, diversity, involvement in the local community, and the impact a company's product or service has on those it serves.

The rationale behind the establishment of this certification system was that there was uncertainty about the scope for a company's management to take account of social purposes (Clark Jr & Babson, 2012). Therefore, it was considered necessary to help these new entities organise their affairs in such a way that they will be able to pursue their dual purpose within the existing regulatory framework. In order to overcome the traditional distinction between non-profit organisations and for-profit ones and its practical weaknesses, the B-Corps model combines profit generation with social benefit in a balanced way. In other words, B Corps represent a shift in the focus of companies towards more ethical practices, which is accompanied by a proof that the commitment is real and not empty promises (Del Baldo, 2019; Honeyman & Jana, 2019).

Before the certification as a 'Certified B Corporation' is awarded, an impact assessment is conducted, during which the company goes under the microscope as a whole, i.e., its management, suppliers, employees, social and environmental impact, so that it is determined whether it meets the requirements for certification. In particular, the B Impact Assessment examines a company's impact on their workers, community, environment, and customers as well as its governance structure and accountability. Questions are split into two categories: Operations, which covers the day-to-day activities, and Impact Business Models, which awards additional points for business models designed to create additional positive impact. Companies have to score at least 80 out of a possible 200 marks in order to become certified, they pay an annual fee of between £500 and £25,000 a year, depending on their size and structure, and they undergo a regular reassessment every two years. The B Impact Assessment is updated every three years to ensure that companies maintain the required minimum standards and work towards their improvement through the feedback provided during the reassessment process.

Apart from the certification, a B Corp constitution must provide that a managing member shall […] give due consideration to […] the long-term prospects and interests of the Company and its members, and the social, economic, legal, or other effects of any action on […] the Stakeholders […], together with the short-term, as well as long-term, interests of its members and the effect of the Company's operations […] on the environment and the economy of the state, the region and the nation (B Corporation, 2013). It is also required to incorporate in the Articles of Association commitments to standards of social and environmental performance, accountability and transparency; and B Corps must sign a declaration that includes a commitment to 'aspire to do no harm' (Woods, 2016).

B Corps are illustrations of a commitment to a 'triple bottom line' approach to business (Elkington, 1998), an accounting framework that incorporates three dimensions of performance: social, environmental and financial, with emphasis on the 3Ps: people, planet and profits. This commitment should not only be mentioned in the company's objects clause, but the whole company should be organised in such a way that it actually has a positive impact on the society and the environment. To put it

differently, the overall fulfilment of obligations to the community, the employees, the customers and the other stakeholders should be measured, audited and reported exactly in the same way as the financial performance of public companies (Norman & MacDonald, 2004).

The scheme started in 2007 and, as of September 2020, there are over 3,522 certified B Corporations across 150 industries in 74 countries. For a voluntary arrangement, its expansion has been remarkable and indicates that there is a growing interest amongst companies internationally for ways to diversify their operation and their business model. Any company of any size can get B Corp certified, even sole traders, as there are no requirements for minimum size. It is important to highlight that B Corporation certification, apart from being entirely voluntary, does not bring any legal significance to a company's shareholders, stakeholders or to its employees. As described above, the certification (B Impact Assessment) allows companies to benchmark themselves against some of the world's leading exponents of 'profit with purpose' business, while the scores of all certified B Corps are publicly disclosed, so there is a very strong incentive to improve. The process highlights the areas of weakness, providing a clear roadmap for improvement and practices that should be implemented. It remains to be seen whether the certification will be applied in a consistent way, while the assessment criteria are flexible enough on the one hand to accommodate all different types of companies and, on the other hand, to reflect the best standards in the market (Bridgers Ventures, 2015). Until then, the recognition that companies, such as Patagonia and Ben and Jerry's, have received shows that the certification brings significant branding benefits to the corporation, including greater outreach, broader recognition and impact. The higher the level of trust that is established between the corporations and the stakeholders, the higher the valuation of the brand and the position in the market. The recent 'B the Change' marketing campaign aimed to encourage certified companies to make greater use of the B Corp branding on their packaging and marketing materials, so that there is more visibility and the consumer body learns more about what the movement is all about and what these companies are trying to achieve.

While there is not much doubt that the B Corps are based on a more pluralist model of governance, there are concerns expressed for the lack of a legislative framework that would monitor compliance with the required standards in a more robust way, due to the fact that within the period between the reassessments, directors have unlimited discretion to shape the company's strategy and operation in any way they deem appropriate without any oversight. Criticisms also focus on the possibility that the B Corps movement undermine the existing social economy and the contribution that charities and charitable trusts have been making (LeClair 2014). The other side of the coin is that B Corps do not necessarily redirect resources away from the civil society into the private sector; quite the contrary, social enterprises can complement charities and help in the expansion of the notion of social purpose to all sectors of the economy (Gehman & Grimes, 2017; Wilburn & Wilburn, 2014). The fact that there is a swift towards companies being committed to have a positive impact through their operation can create a momentum for a 'new social contract developing between business and society, in which businesses engage with stakeholders beyond their

current narrow remit to create benefits for employees, citizens and society at large' (Advisory Panel to the Mission-led Business Review, 2016, p. 3).

B Corp UK, the organisation responsible for trying to implement B Corporations in England and Wales, was hoping to sign up roughly 50 B Corps in 2015 and there are currently 275 companies that are Certified B Corporations across many industries including legal services, advertising, accounting, telecommunications, even hairdressing! Some of the most notable companies that have achieved certification are the Jamie Oliver Group, Activia, Danone and Abel & Cole. Taking into account that the UK is widely recognised as having the most highly evolved social enterprise sector in the world, it is rather surprising that on the one hand Benefit Corporation legislation does not exist in the UK, while on the other hand the B Corps certification system has not really taken off. There can be two explanations for this: at first, that the UK Companies Act 2006 is a very flexible instrument, designed to enable businesses to have regard to different groups of stakeholders through the duty of directors to promote the success of the company. Despite the concerns as to the enforceability of this duty and the overall success of the Act to instil a more enlightened way of doing business in the UK, people are still sceptical regarding the extent to which B Corps really have a different *modus operandi*. The second justification is that there is the Community Interest Company and, as it will be discussed in the next section, this form has managed to create strong supporters within the UK markets and business community in general.

4 Community Interest Companies (CIC)

'The CIC idea was initially hatched over a bottle of claret in Balls Brothers Wine Bar in Cheapside by myself and Roger Warren-Evans, a serial social entrepreneur' (Fisher & Ormerod, 2013). This is how Stephen Lloyd, the founding father of CICs, described the formation of the idea behind this *sui generis* corporate form. Their motivation was that they were dissatisfied by the reduced status and low profile of industrial and providence societies and they agreed that there was room for a new legal form for social enterprises. The government endorsed their plans for creating public interest companies and shortly after the Community Interest Company, a special form of social enterprise, was introduced in the United Kingdom under the Companies Audit Investigations and Community Enterprise Act 2004. The 2004 Companies Act became especially effective when given effect by two subsequent Regulations: the Community Interest Company Regulations of 2005 and the Community Interest Company (Amendment) Regulations of 2009. The first CIC incorporated in the United Kingdom on 11th August 2005 and 15 years later there are more than 15,700 CICs on the public register providing community benefit in all business types across the UK. The rapid growth and the fact that CICs quickly outnumbered both cooperatives and mutual, two quite old and traditional corporate structures, serves as evidence that the establishment of the CIC has been a very positive development and a successful addition to the business vehicles available in the UK business environment.

From the beginning, it became apparent that the whole concept of benefit corporations was applied differently in the UK compared to the US. For example, up until 2015 a close look at the companies that have applied to B Lab to become B Corps in the United Kingdom, the majority were small and medium-sized businesses, not large or multinational companies that would try to get access to foreign markets and sell their products internationally (Williams-Grut, 2015). The motivation has been different and, despite the fact that companies can significantly benefit from the B Corp branding, increased awareness and wider profit margins at a global basis, CICs seem to be more focused on the local communities within their country of registration, such as nurseries, community groups, spin-outs from health, youth services and other public sector areas. It would not be an exaggeration to say that CICs bear greater resemblance to non-profit organisations rather than for-profit businesses (Borzaga et al., 2020). This motivation can be seen in the UK government's website, where it is mentioned that CICs are effectively companies 'working for the benefit of the community' (Department for Business, Energy and Industrial Strategy, 2016a, p. 5), providing services by and for communities. Another interesting fact is that a significant number of CICs, especially during the first years after the introduction of the CIC form, have been companies limited by guarantee, which in practice means that they can never pay out dividends, as they have no share capital and no shareholders. Of course, this can change as time goes by, depending on the nature of the CIC's business, because if private investors wish to invest in the company, they cannot get shares.

According to the 2005 Regulations, companies (both limited by shares and limited by guarantee) can be re-registered as CICs (DBEIS, Chapter 4, 2016c). In order to be registered as a CIC, a company must declare how it will benefit society, providing information about the nature of the community interest that it will pursue. This statement of purpose is also being assessed through a 'community interest test', which stipulates that 'a reasonable person might consider that its activities are being carried on for the benefit of the community' (Companies (Audit, Investigations and Community Enterprise) Act 2004, section 35). For example, the pursuit of political aims, such as support for political campaigns, is not allowed (DBEIS, Chapter 2, 2016b, section 4.6). Any benefits or advantages provided by the company in the context of its operation should favour the wider community. Having said this, in the event that specific social groups are favoured, as long as this does not undermine the genuineness of the social purpose pursued (DBEIS, Chapter 2, 2016b, section 2.3). Such examples are when a hospital is built, a museum is established or clinical trials are supported.

From a practical point of view, companies limited by guarantee must either reinvest their profits in the company or use the profits for social purposes. Companies limited by shares must combine the pursuit of the stated social purpose with the promotion of their success, financial or of any other kind. The transformation into a benefit corporation requires a 75% majority of the shareholders and any minority shareholders, who wish to express their opposition to the conversion, can refer the matter to the courts within 28 days, with a view to have the decision blocked.

CICs are regulated by the CIC Regulator, an independent statutory office holder, appointed by the Secretary of State. The Regulator is responsible to screen companies that seek registration as CICs and monitors their activities, due to the fact that CICs are subject to restrictions regarding the payment of dividends, transfer of assets and capital investment. The Regulations governing CICs do not contain any special guidelines or any specific provisions on the duties of management, other than the implicit obligation to pursue social purposes (DBEIS, Chapter 9, 2016e, p. 4). All CICs must publicly file a 'CIC Report' within 21 months of incorporation (and subsequently, annually), describing the actions the CIC has taken to benefit the community in line with the company's initially stated community interest purpose (Regulator of Community Interest Companies, 2015, p. 18).

The Regulator is entrusted with the task of facilitating the formation of CICs. More specifically, the Regulator will not take an inflexible or bureaucratic approach towards new applications and an attempt will be made to resolve any problems informally and without undue delays. However, this does not imply any pro-active supervision of individual CICs or any pre-judgement by the Regulator (DBEIS, Chapter 11, 2016g, section 11.1). For example, in 2009–2010 1,572 applications were received, out of which 1,298 were accepted (Department for Business, Innovation and Skills, 2011, p. 7). In 2016 the applications received were 4,007, but there was a 30% rejection rate (Community Interest Companies Blog, 2017). These statistics indicate that the scrutiny can be quite robust, and a certain level of minimum standards needs to be met before certification is provided. In this way, there is a degree of certainty that all social enterprises that have received the certificate by the authorities are in compliance with the requirements of the law.

In the US, some states have introduced a requirement for benefit corporations to appoint a 'benefit director', who is responsible for monitoring, on a continuing basis, whether the company complies with its obligation to pursue or create public benefit or a specific public benefit. Although the respective laws do not provide for any liability to pay compensation in case this obligation is breached, there is an element of monitoring on a continuous basis after registration, which can be seen as an additional mechanism of checks and balances that ensures that the pursuit of the social purpose is not abandoned.[2] Equally, as it was discussed above, B Corps also have to be re-certified every 2 years and since the assessment criteria are being updated regularly in response to the current best practices, it can be more difficult and demanding to reach the required score each time.

When a company's primary purpose is of a social nature, this inevitably raises the question of whether the stakeholders whose interests the company has to serve should be able to sue the company in the event that their interests are not promoted in line with the company's stated purpose. In the UK, stakeholders cannot sue a CIC, but they can complain to the Regulator, who can in turn examine the complaints, ask for additional information or evidence in order to verify the validity of these

[2] Benefit directors are mandatory in Hawaii, New Jersey and Vermont. Section 302 of the Model Legislation for benefit corporations made provision for there to be a mandatory benefit director for all publicly traded corporations.

complaints (DBEIS, Chapter 11, 2016g, p. 11.4–5). Moreover, pursuant to section 31 of the Companies (Audit, Investigations and Community Enterprise) Act 2004, the Regulator can appoint, suspend or dismiss members of the board of directors where: (a) there is misconduct or mismanagement; (b) it is necessary to protect the assets of the company; (c) the company fails the "community interest" test mentioned above; or (d) the company does not carry on any activities in pursuit of its social purpose. The Regulator has also the power to institute proceedings with a view to winding up the company (DBEIS, Chapter 11, 2016g, section 11.4.2.6).

When a company has a very broad or generic statement of purpose and, in light of the fact that there are no guidelines about the actual fulfilment of the social purposes or strict rules about management liability, it would be extremely difficult to stipulate such a right for the stakeholders. In particular, it would be really challenging to identify the stakeholders, who have a right of action,[3] there will be uncertainty about the risk of liability and stakeholders deciding to start proceedings would be sailing in uncharted waters, as it will be hard to prove to what extent a company's management has fulfilled its obligations towards them (Sørensen & Neville, 2014, pp. 296–297). At this point, it is worth mentioning that in the US certified companies play the role of the watchdog themselves as to whether the other certified companies continue to fulfil the requirements for certification and it is thus not unheard for the B Lab to receive complaints from other certified undertakings (Sørensen & Neville, 2014, p. 298). This system of 'checks and balances' offers an effective solution to the problem of limited resources of the regulators or the supervisory authorities and can be characterised as self-monitoring, because it is the market participants themselves who are monitoring each other and are responsible to report any breaches that they may come across. The other side of the coin is that it is possible that complaints can be made without any support from evidence or based on rumours and suspicions or they can be driven by indecent motivations, such as to harm or eliminate the competition. Of course, such practices, apart from being unethical and unprofessional, do not fit with the whole purpose of social enterprises and should thus be avoided.

Reference needs to be made on the issue of how profits will be used and what proportion will be distributed to shareholders through dividends, the approach taken by the UK is that there should be restrictions on the shareholders' discretion on the transfer of assets, such as payment of dividends or asset disposal, especially in the event of winding up or reincorporation as an ordinary company. A CIC can only pay its shareholders a maximum dividend of 5% over the Bank of England base rate. Only 35% of a CIC's distributable profits in any one year can be paid out in private dividends to shareholders; the rest must be kept in support of the CIC's mission. Until the law changed in 2014, there was a double asset lock: in addition to the 35% restriction, dividends could total no more than 20% of the value of the

[3] In companies that have adopted a two-tier board system, it would be perhaps easier to monitor the conduct of directors and through employee or stakeholder representation open the avenue for directors' liability.

shares held.[4] In case that dividends are not paid in one year, the amount payable can be carried forward and be used in the distribution of profits in the following year. In the context of the adoption of the rules related to CICs, there was a number of proposals about dividends and distribution of profits, but this model was supported as more compatible with the whole idea behind the creation of CICs (Cross, 2004). An alternative solution could be to require that a payment be made for social purposes if it was decided that dividends would be paid to the company's shareholders. In this way, the company would in principle fulfil its dual purpose, as the company would in fact justify that it has sufficient financial resources to invest in the fulfilment of its social purpose as well as pay its shareholders without endangering the company's financial stability (Sørensen & Neville, 2014, p. 300).

In terms of other kinds of disbursements, it is worth mentioning that pursuant to section 30 of the Community Interest Company Regulations 2005:

(a) a CIC can only buy back shares at a price corresponding to what was paid for them;
(b) if a reduction of capital is decided, a CIC may not pay out on shares that have not been fully paid up, and the maximum that can be paid out is equal to a fully paid-up share;
(c) the maximum interest that can be paid on a loan where payment is dependent on the company's profits is 10% of the principal; the rationale behind this rule is to prevent owners from providing loans instead of buying shares so as to avoid the above restrictions on the payment of dividends;
(d) the directors of a CIC only receive reasonable salaries or fees and the reasonableness of these is monitored as per the provisions of the 2005 Regulations.

The imposition of all the above mentioned restrictions (asset locks[5]) aims at preventing greenwashing[6] and protecting the social character of CICs. The wording of the rules reflects an attempt to limit the flexibility allowed to shareholders and prevent practices whereby the profits are paid back to the shareholders instead of being used for the pursuit of the company's social purpose. For instance, in relation to the directors' salaries, there are no criteria as to what constitutes a reasonable salary or a formula that would allow the authorities to set minimum or maximum standards for the companies to adhere to. The restriction is clearly aimed to prevent

[4] Community Interest Company Regulations 2005, section 17ff. Under section 30 of the Companies (Audit, Investigations and Community Enterprise) Act 2004, the Regulator has authority to determine the limits for dividend payments and other disbursements.

[5] An asset lock is a commitment by CICs and those who set them up to lock profits and assets into the company irrevocably, through the implementation of the following two measures: (a) prohibit or impose limits on the distribution of assets by community interest companies to their members, and (b) impose limits on the payment of interests on debentures issued by, or debts of, community interest companies.

[6] The flipside of this trend towards increased transparency is the risk of 'green washing' or 'purpose-washing' where large businesses present a social or environmental front that is not backed up by realised social or environmental impact. It can be hard to distinguish between a company that is genuinely creating value for society and the environment, from one that is good at marketing.

the manipulation of the companies' financial statements and the undue setting of the levels of the executive pay (DBEIS, Chapter 6, 2016d, section 9.3.6).

A more important set of restrictions is related to the CICs' de-registration and conversion. A CIC is not allowed to convert into an ordinary company (DBEIS, Chapter 10, 2016f, section 10.5). It is not possible for a CIC to simply denounce their social purpose and decide to become a normal 'for profit' company, because there would be room for fraudulent activities through companies opting in and out of the CIC scheme. If the conversion of a CIC into a normal company would be allowed, the shareholders would be able to take control of all the assets created during the period that the company was operating as a CIC without any obligation to account for them to the stakeholders. Therefore, it is decided that a CIC is wound up, its assets cannot be distributed to the shareholders. Shareholders may only be paid an amount corresponding to their original capital investment in the company, while the remaining assets must be allocated to other CICs. If the articles of association of the CIC in question does not specify which CIC(s) should receive the assets in the event of its winding up, then the Regulator will decide (DBEIS, Chapter 10, 2016f, section 10.4.4). The only conversion that is allowed is the conversion of a CIC into a charitable trust or an Industrial and Provident Society, and the company's assets will be entirely devoted to social purposes (DBEIS, Chapter 10, 2016f, section 10.2 and 3). Interestingly, according to section 105(a) of the Model Benefit Corporation Legislation 2017, in benefit corporations a conversion into a normal corporation is allowed without any restriction related to the use of the assets as long as the decision has the support of the two thirds of the shareholders.

The restrictions described above are supplemented by reporting requirements, which promote transparency, so that the company's stakeholders as well as the authorities are informed about the CICs' performance, especially in relation to the fulfilment of the social purposes. This is why the 2005 Regulations specifically mention that the reporting obligations must cover how the company has served the community interest, how the company has consulted the interest groups affected by the company's activities (and the results of these consultations), information about payments to directors, information about dividends, information about payments of interest on loans which are dependent on the company's profitability and a review of activities carried out by the company without charging a full fee (section 26ff). These reporting requirements cannot be considered as excessive compared to the information that public companies are required to disclose. In addition, the social purpose that these companies pursue make the content of such disclosures significant not only for its own shareholders, but also for competitors, investors interested in investing and the interest groups which are to benefit from the social purpose pursued (Nicholls, 2010).

Before moving on, it is essential to engage with the criticism that the CIC form has received and the drawbacks that have been identified so far by academics and practitioners.

One quite commonly argued criticism in relation to CICs is that this corporate form can easily be used by 'weasely people who want to hide behind a veneer of social benefit without the same level of accountability' (Senscot, 2015). This line of thought is based on the premise that charities can be used if the aim of the business is

to have social impact, instead of using CICs, which offer 'the simplicity of company structure without the extra level of governance' and 'a less intense regulatory regime', considering that the Office of the Regulator is a rather 'light-touch and rarely goes public when following up [with] complaints' (Third Sector, 2015). It is true that the Regulator openly acknowledges that its role is intended to be light-touch, but this does not mean that it will allow abuses or it will not apply the Complaints Procedure Protocol in the event that complaints are received. In particular, the fact that CICs seem to work closely with the local communities is indicative of their intention to be more transparent and directly accountable to the same local communities that they intend to work for. The pressure from such communities can be substantially the same as the reputational damage in the event that the CICs fail to live up to the expectations created by their purpose statement.

Phil Horrell, the Office Manager at the CIC Regulator, argued that a CIC "theoretically offers greater potential for rapid expansion and diversification, not only because of the looser financial regulation but also because of the greater opportunities for raising capital" (Jump, 2007). However, he emphasised that the choice between a charity and a CIC is an important one, same as the distinction between these two forms. In particular, CICs and charities are two separate entities because they cover two distinct degrees of benefit: benefit to the community and general public benefit (Edmonds, 2014). Charities must pass a different test, the charitable test of public benefit, not the community interest test as the CIC. Therefore, a company should decide to become a CIC over a charity mainly to "be branded as a social business" that the public will view "like [a] charit[y]" while still operating under the "dynamism" of for-profit businesses (Brakman Reiser, 2013; Jump, 2007). Perhaps, the UK government and the Regulator should try to draw some inspiration from the US and promote more the CIC brand and its value as a business vehicle for global expansion even under demanding market circumstances, as the ones that currently exist (Cho, 2017).

Another issue that has attracted criticism is the lack of any provisions granting tax relief for the CICs, as it is the case for charities. A CIC is not entitled to any specific corporation tax exemptions and its profits are fully taxable unless it can be shown that the terms of the contract are such that, in tax law, the organisation does not amount to a taxable trade. In the majority of cases, a CIC will enter into a contract with a third party to provide goods or services and it is difficult to see the contract as anything other than a commercial arrangement freely entered into. This leaves the question of whether the services are provided for reward or, perhaps more meaningfully, with a view to profit. A CIC is, of course, required under its articles of association to apply any profits for the benefit of the community. However, this not-for-profit motive does not affect the corporation tax position on earning profits; it merely directs how those profits are to be applied. A CIC's not-for-profit motive does not, therefore, affect its corporation tax status (Batty, 2015). Until now, there is no evidence to support that there will be a change of approach in relation to tax reliefs or lower corporate tax rates for CIC any time soon, so it is unlikely that this concern will be addressed by the government in the short-run.

5 Reflecting on the Present and Looking at the Future

In 2015, the United Nations approved the 2030 Agenda on Sustainable Development, which includes 17 Sustainable Development Goals (SDGs), ranging from the elimination of poverty to the fight against climate change, education, equality of women and the defence of the environment. After the initial euphoria for the new agenda, the reality check indicated that achieving the SDGs would require an amount between USD 5 and 7 trillion per year (Avrampou et al., 2019; UN, 2014). Such an amount is hard to be secured through exclusive reliance on public resources, so the only viable option is the involvement of a wider range of actors, such as governmental organisations, the private sector, civil society, companies as well as individual citizens (Bebbington & Unerman, 2018; Scheyvens et al., 2016). The beginning of the new era was hailed by Larry Fink, the CEO of BlackRock, who encouraged corporate executives to work towards the creation of companies more committed to their social role (Bruner, 2013; Van Zanten & Van Tulder, 2018). Sustainability and sustainable development were the new corporate buzzwords, but, unlike Corporate Social Responsibility, had to be integrated into corporate strategies, policies and organisational structures. Companies were obliged to find ways to create value internalising Environmental, Social, Governance (ESG) elements into their corporate decision-making (Busco et al., 2017; Diez-Busto et al., 2021). While no company is inherently geared towards unsustainability, there are countless examples of unsustainable business practices, which are supposed to be in line with dominant legal and economic theories of corporate governance (Sjåfjell et al., 2015). Therefore, the challenge is to maintain a delicate balance which will enable them to have a positive effect on long-term financial performance.

The first signs have been encouraging at international level, as indicated by the Global Sustainable Investment Review, which confirmed that sustainable investment increased by 34% between 2016 and 2018 in Europe, United States, Japan, Canada and Australia-New Zealand (Paelman et al., 2020). Of course, the initial effect of the B Corp certification was a 20% slowdown in revenue as well as a slowdown in business growth (Gamble et al., 2019), which re-affirms that becoming a B Corp is not window-dressing and a box-ticking exercise; it requires structural changes and the adoption of a new business philosophy. Looking at the other side of this coin, it can be seen that the new business models, such as the B Corp, are in fact vehicles for change and tools for the generation of social impact. Sheer profit maximisation is removed from the list of priorities and profit-making becomes effectively the means by which these companies achieve their social purpose (Stubbs, 2017).

Nevertheless, we have to be very careful in the next steps, showing that we have learnt from the mistakes of the past. The shareholder wealth maximisation model is still deeply embedded into our society and business community, so it is not easy to simply deviate from it. It would be mistaken to try and replace it with a simple sustainability maximand. Instead, the efforts should be focused on education and raising awareness regarding sustainable business and finance and the integration of social, cultural, economic and environmental elements into the foundations of

modern corporations (Leach et al., 2013). Redefining corporate purpose and reshaping directors' duties will definitely help, but it will be a long process until compartmentalisation, silo-thinking and incoherence in laws and policies are eliminated; therefore, in the meantime, giving support to new initiatives, such as B Corps and CICs, sends the message that we cannot afford to rely on path-dependent and obsolete ideas just because we are feeling comfortable with them (Sjåfjell, 2020; Sjåfjell & Mähönen, 2022). Corporate decision-making must adopt new and ambitious ideas in order to leave the past behind and move towards a sustainable future.

6 Conclusion

In the early years of the development of the CICs in the UK, it was noted that this corporate form 'assumes [there is] a pool of investors with an appetite for wedding financial and social return and sufficient brand awareness and confidence to appeal to them... [It also], however, requires these investors to be especially devoted to the blended enterprise concept by substantially limiting the upside of their investments' (Brakman Reiser, 2010). While it seems that this has not been a deterring factor for entrepreneurs and investors, at least looking at the number of CICs registered so far, time will show whether the CIC form will stand the test of time and to what extent it can play a central role in the UK's corporate sector. It is also very difficult to predict whether it will expand to all industries and sectors of the economy and it will be of critical importance whether multinational corporations will be tempted to become CICs or use this form for their subsidiaries (Liao, 2015). Equally, it has to be seen how well CICs will cope with the competition that B Corps and benefit corporations will create in the next few years. Even if the CIC model becomes a credible complementary model to the traditional/mainstream corporate models, it will be a huge success, because it will definitely challenge them and it will oblige corporate executives to re-think the purpose and mission of their companies.

This conclusion is based on the fact that more and more jurisdictions have been introducing or are seriously considering introducing new or hybrid structures with a more social orientation. All these new initiatives, such as B Corps and CICs, are voluntary and still represent a trend, not an integral part of the international business landscape. They need to evolve, improve and become more attractive. One of the major challenges in regulating social enterprises is to find a solution that is both flexible and credible. On the one hand, it is necessary to ensure that companies that are designated 'social enterprises' do indeed pursue social goals. This may call for specific requirements for qualification as a social enterprise, as well as restrictions on what companies may do as long as they are classified as social enterprises.

On the other hand, the regulations should be sufficiently flexible, so that the social enterprise regime is not solely for those whose activities have a purely charitable aim. It is not easy to balance the interests of those who are profit-driven and those who wish to pursue social purposes (Sørensen & Neville, 2014). However, what should not be overlooked is the fact that the topics of social economy, social enterprises

and corporate pluralism are now part of the agenda of discussion at all international political, economic and business forums. Even if the discussion takes a long time to mature and lead to any resolutions or initiatives, at least an exchange of views has been initiated and, as long this exchange does not halt to a stop, this is a positive development.

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Identifying Significant Shifts in Operating Environments: The Role of Corporate Governance

David Starr-Glass

Abstract Corporations possess unique legal attributes that provide shareholders with asymmetric advantages and protections in the marketplace. Created and sanctioned by the state, corporations remain abstractions until they are populated by people—shareholders, managers, and directors—and commence their activities. Those who populate the corporation, and those who engage with it, construct their own understandings of what corporations are and how they should behave. Of key importance in this chapter are those who understand corporations in three different ways: legal, economic, or political entities. These mental constructions and meanings shape the activities, behaviors, and operational goals of the corporation as it engages with its external environment. One persistent characteristic of that external environment is change, which sometimes can be slight and incremental and sometimes significant and disruptive. This chapter suggests that the recognitions and perceptions of long-term environmental change are viewed differently by those who understand the corporation as either an economic or a political entity. It recommends that successfully recognizing and confronting long-term change requires corporate governance that is future-orientated, strategically flexible, and diverse in terms of understanding the nature and purpose of the corporation.

Keywords Affordances · Agency theory · Construction of meaning · Diversity · Managerialism · Shareholders · Strategic formulation

1 Introduction

This chapter looks at the corporate landscape, a landscape that is inevitably going to be subject to change. Change will take place within the corporation itself, but—the focus of this chapter—change will also occur in its external or operating environment. The process of responding to change begins with its detection: change recognition is the initiating factor. However, for the corporation, recognizing that change has

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occurred in external environments and that a response is warranted is complicated and mediated by multiple factors. This chapter centers on one of these: the way in which senior management and corporate directors understand the nature of the corporation, conceptualize its function, and envisage its future.

Appreciating how corporations confront external change—particularly pervasive disruption such as climate change, energy insecurity, and environmental degradation—begins with an understanding of how its members make sense of the corporation and conceptualize its actions and behavior. We need to understand how they consider and answer questions such as: What is a corporation; what does a corporation do; to whom is the corporation responsible; and—informed by these answers—how should decisions be formulated about future actions and behaviors?

Obviously, there is a multiplicity of answers that reflect the different perspectives, experiences, and agendas of those who pose the questions. This chapter centers on positive—rather than normative—statements about the nature, function, and future of the corporation. It tries to represent the corporate landscape as it presently *is*, not as it *might* be, or *could* be, or *should* be. In time—and through economic, social, and political change—normative statements can morph into positive ones. However, for many observers, potential confusion and enduring disenchantment with the corporation and its governance comes from an eagerness to envisage it as it might be, rather than to acknowledge it as is.

The chapter has three central premises: (a) corporate members create their individual *understandings* of the nature and the role of corporations, dressing the abstraction with constructed meaning; (b) in the process, corporate members come to recognize the *affordances* that the corporation provides and suggests; and (c) based on a recognition of these affordances, corporate members identify issues, frame questions, and formulate decisions about the corporation's future.

In this context, *affordances* are "functional and relational aspects, which frame, while not determining, the possibilities for agentic action in relation to an object" (Hutchby, 2002: 444). Corporations—as mentally constructed but ostensibly functional entities—are artifacts in our economic, social, and political worlds that "may be both shaped by and shaping of the practices humans use in interacting with, around and through them" (Hutchby, 2002: 444).

Corporate members adopt roles, assume responsibilities, and commit to outlooks that resonate with their understandings and mental constructions of the corporation. A number of constructions seem to be common: the corporation imagined as a legal, economic, or political entity. It is suggested that corporate roles, responsibilities, and perspectives emerge consequentially from the individual's underlying understanding of the nature and function of the corporation as a legal, economic, or political entity. It should be noted that while recognizing these major mental constructions is helpful, it is not inferred that individuals need to possess them or cannot understand differently.

Before beginning to examine the corporation and how it might respond and adapt to significant disruption in its external environment, it might be helpful to lay out the structure of the chapter for the reader. These sections follow this introduction.

Section 2 explores the question of what is understood by "a corporation". Section 3 considers the intrinsic nature of the corporate form and the advantages, possibilities,

and affordances that it possesses. The following section considers two common ways in which the corporation has been understood: as an economic entity or as a political entity. Section 5 examines the different perspectives that people might have regarding how the corporation should be navigated through its social and economic environments. This is followed by a section that looks at the inevitability and nature of change in the corporation's operating environment. Section 7 argues that management and governance must come together to recognize and facilitate a response to change—especially to significant and disruptive change—in the firm's operating environment. The final section briefly summarizes the main points of the chapter and suggests ways in which we might improve our understanding of corporations in action.

2 What Is a Corporation?

As a starting point in an exploration of the corporation and its behavior, we consider a simple question with a less than simple answer: What exactly do we mean by a corporation?

2.1 Ingenious Invention

The corporate entity, as a legal such as benefit corporations form of engaging in the economic and social world such as benefit corporations, has a remarkably long and enduring presence. It was an invention of Roman law, but only really came to prominence in medieval Europe, where it was adopted as the preferred way of organizing and operating civic and academic organizations. In the Commercial Revolution, which took place in Europe between 900 and 1,500 CE, many cities opted to reorganize along corporate lines as did newly emerging universities—"first in Bologna in the eleventh century, then 50 more in the following four centuries" (Cantoni & Yuchtman, 2014: 824).

The corporate form, particularly its quality of possessing legal such as benefit corporations immortality, provided a mechanism for establishing, growing, and perpetuating organizational activity such as benefit corporations. The eminent nineteenth century English legal such as benefit corporations scholars and historians, Pollock and Maitland (see Brunner, 1896), observed that all later commercially engaged and economically orientated corporations were direct descendants of those "corporations of one small class, the learned corporations that were founded in the twelfth and thirteenth centuries, and others that in later days were fashioned after their likeness" (Pollock & Maitland, 1898: 459).

With slight modification and adaption, the corporate vehicle was enthusiastically utilized by the great merchant adventurer organizations such as the English East India and Dutch East India Companies (Anderson et al., 1983; Donoghue, 2020; Seth, 2012). Joint-stock corporations allowed multiple shareholders with moderate

wealth to participate in vast economic ventures and provided them with limited liability: risk and liability were reduced, not eliminated. The disastrous failure of the ill-fated Darian Venture of 1699—a venture that was over ambitious, excessively risk burdened, and ineffectively managed—sent a shock wave through the investing and speculating classes of Europe. However, it did little to lessen interest in, or appetite for, joint-stock ventures—even although the Darien catastrophe decimated Scottish private wealth, reduced the nation's fiscal and political power, and decreased opposition to the country's eventual union with England in 1707 (Armitage, 1995; Novak, 2018).

Perceived value of the corporation, and hence its utilization in business ventures, peaked at the outset of the 1st Industrial Revolution, which began in Europe towards the end of the eighteenth century. The corporation proved itself to be a particularly effective economic and financial vehicle, providing multiple advantages, safeguards, and protections for investors who were focused on long-term wealth accumulation. From this point on, most businesses—and particularly large-scale business ventures—organized themselves and operated along corporate lines.

It is hard to overestimate the utility that the corporate form provided for economic growth or to overstate its contribution to the development of the social and political worlds. Of course, corporations need not necessarily be created with profit maximization and wealth accumulation in mind. They have the potential of being used in this way, but that is a license not a requirement. The corporate form has been utilized by governmental agencies (the second sector of the economy), not-for profits (third sector), and for-benefit enterprises (fourth sector) (Corry, 2010; Sabeti, 2011).

- Butler saw the corporation as "one of the most successful inventions in history, as evidenced by its widespread adoption and survival as a primary vehicle of capitalism over the past century" (1989: 99).
- Greenwood considered the corporation "an entirely new creature" that provided "a vehicle for economic enterprise [that was] freed to pursue private interest… [so that] investors and control parties were almost entirely relieved of responsibility or liability for corporate actions" (2017: 177).
- Ireland observed that corporate "emergence and development… was not the economically-determined product of efficiency-driven evolution. It was, rather, in significant part the product of the growing political power and influence of the financial property owning class" (2010: 853).

So is the corporation best described as one of the most successful inventions in history, or as an entirely new creature, or as a unique product of the growing political power and influence of the financial property owning class? In reality, it is all of these and much more.

2.2 Multiple Understandings

There are two broad ways of defining or of specifying what is meant by "a corporation". From a teleological perspective, these definitions can be either *intrinsic* understandings (that is, initial and inherent) or *extrinsic* understandings such as benefit corporations (subsequent and consequential).

- **Intrinsic understanding**. This way of making sense of an object or phenomenon focuses on its inherent qualities, characteristic, and perceived affordances. This understanding is concerned with present observable realities, rather than with future possibilities and potentials. For example, this spoon is understood to be an elegantly shaped and creatively designed piece of steel. That is what we see it to be, that is the meaning that we attach to it, and that is what it will continue to be in the future. Different subsequent understandings do not erase intrinsic ones, although they may displace them.
- **Extrinsic understanding**. This sense-making approach focuses on the usages that have been made or could be made of the object. Extrinsic understandings accentuate purpose and end-use. They are future-orientated as opposed to present-orientated. Teleological explanations and definitions look towards the realizations and exploitation of possibilities, not to the mere presence of such potentials (Greek: *telos*—an end, goal, fulfillment, completion). The spoon is not simply an elegantly shaped and creatively designed piece of steel: its affordances are recognized and utilized—it is understood to be an effective utensil for consuming food (Davis & Chouinard, 2016; Norman, 1988). The spoon might also be reasonably construed as an implement for hammering in nails. Subsequent experimentation and experience might validate that way of understanding spoons or, more likely, they might prompt a significant reconsideration of this purpose.

Intrinsic conceptualizations of the corporation consider its inherent attributes and center on legal possibilities—the corporation is, after all, a creation of the law. These conceptualizations allow us to understand, in more absolute terms, what corporations *are*—what the corporate form provides—without being concerned about what the corporation-in-action actually *does* or *should do*. This allows us to appreciate the corporation in what might be considered conceptual terms—conceptual in the sense of inherent and potential, rather than dictating how it might be used.

Extrinsic ways of understanding and defining the corporation, on the other hand, start with an acknowledgement of its conceptual nature, its legal origins, and its intrinsic attributes. However, they then go on to imagine or reify ways in which the corporation could be used or has been operated. The point of reference for extrinsic understandings is more likely to be located in present experience and perceived consequences, rather than in historical potentials or possibilities.

Those located within the corporation—and those who are within its sphere of influence—do not usually or necessarily perceive it to be a legal entity. Corporate members may be well aware of its legal form and existence; however, this is not what they recognize on a day-to-day basis and this is not what they believe they are

interacting with. They perceive the corporation quite differently. Exactly what they understand it to be may differ. However, their perceptions are critical, because they inform the subsequent behavior of corporate members and how those associated with corporations expect the corporation to act.

For example, Veldman and Willmott (2013)—who have contributed thoughtfully and imaginatively to this field of study—argue that the corporation can be understood from three different perspectives: as a legal, economic, or political entity. These scholars contend that each perspective or understanding is a socially constructed representation that has been assembled in an attempt to reify the abstract nature of "the corporation". Each understanding provides an accurate and reliable conceptualization of the corporation. Incidentally, Veldman and Willmott use the term *imaginaries*: accentuating the perceived and understood "image", rather than inferring an illusion.

In reality, and over time, individuals have more than a single imaginary or understanding of the corporation. They learn to see it from another perspective and they share their understandings with others. Understandings are fluid: they can change and they can be changed. In time, separate understandings become "intertwined to the effect that they often mutually reinforce and contradict one another…. analytically distinguishable, they are practically enmeshed" (Veldman & Willmott, 2013: para. 3).

Nevertheless, we contend that individuals tend to associate more strongly with one understanding and that understanding becomes dominant and preferred.

3 Corporations Understood as Legal Entities

From this perspective, corporations are viewed as a particular legal vehicle for organizing business ventures and engaging in economic transactions. The state permits the corporation to assume a distinct, independent, legal identity with property rights over its pooled assets and limited liability with regards to creditors. The corporation is able to enter into contractual arrangements, pursue legal remedies, and be pursued by those wishing to bring legal remedies against it. In many ways, the corporation is a newly constituted person—a legal person, not a natural one—and possesses legal obligations, contractual capacity, and property rights not dissimilar from others in society.

However, incorporation does not aim to reproduce a natural person—the point is not to produce an entity that is *a part* of society, but rather to create an entity that is distinctly *apart* from it.

3.1 Legal Possibilities, Potentials, and Affordances

As a legal entity, the corporation (Latin: *corpus*—a body) resembles the medieval Golem of Prague: a human representation, fashioned from clay, which was created to

protect and defend the local Jewish community in times of persecution. The Golem (Hebrew: *golem*—an undifferentiated mass, embryo, chrysalis) was inanimate and functionless until it had, in a mystical sense, the spirit of life breathed into it. The primary life force for the corporation comes in the form of financial assets and capital contributed by shareholders.

There is also a secondary life force that vivifies the inanimate corporation. This occurs when the legal shell is populated with corporate members, who direct its activities. The corporation is nothing without its shareholders' capital; little without the efforts of its different corporate members.

Legally, the corporation provides shareholders with a set of possibilities and protections that would not otherwise exist:

(a) **Limited shareholder liability**. This significant feature of the corporation, from the shareholders' perspective, is "a form of *owner shielding* that [operates] by protecting personal assets of firm owners from the claims of firm creditors" (Hansmann et al., 2006: 1336, emphasis in original). In essence, the "notion that the corporate entity, rather than its shareholders, owns its assets is a condition of the possibility of establishing limited liability" (Veldman & Willmott, 2013: para. 13).

Since it is corporations—not individual shareholders—that enter the marketplace and engage in economic transactions, creditors face a corporate asset cap on the amount of claims that they can receive in cases of financial failure or bankruptcy.

(b) **Shareholder asset shielding**. This is the reciprocal of limited liability. Since contributed shareholder capital and assets belong to the corporation, personal financial claims against shareholders are limited and restricted. The corporate entity shields its shareholders by restricting the rights of personal creditors and "subordinating their claims on firm assets to those of firm creditors… strong entity shielding additionally limits their ability to liquidate firm assets" (Hansmann et al., 2006: 1338).

Taken in conjunction with limited liability, the risk and reward profiles faced by those behind and in front of the corporate veil are asymmetrical. In adverse circumstances, shareholders are only vulnerable to the extent of their capital investment, but they are protected from what might be the fuller and greater losses sustained by the corporation. As the English jurist Edward Cox put it, the corporation "permits a man to avail himself of acts if advantageous to him, and not to be responsible for them if they should be disadvantageous; to speculate for profits without being liable for losses" (quoted in Ireland, 2010: 844).

(c) **Continuing and indefinite life**. Unlike ordinary mortals, the legally created corporation has an indefinite and continuing life, unless otherwise stipulated. "A separate *indivisible legal personality* for the corporation ensures that it has a life of its own, and does not have to be broken up (and reconstituted) if any of its owners or employees die or leave" (Rajan, 2012: 188, emphasis in original). Clearly, legally granted immortality has profound and highly desirable consequences for corporations as entities and for their shareholders. They can engage

in continuous restructuring and future orientated strategic planning. They can confidently embark on long-term enterprise building and engage in uninterrupted wealth accumulation. They can concentrate on long-term economic growth that would be unreasonable, if not impossible, for natural persons and other forms of business, such as sole proprietorships and normal partnerships (Starr-Glass, 2018).

3.2 Corporate Member Perspectives

It is perilous to infer the attitudes and perspectives of those who consider corporations as legal entities. As will be discussed later, it is more likely that corporate members will understand the corporation not in terms of a legal entity but as an economic or political actor. Nevertheless, for those who privilege a legal conceptualization of the corporation, the salient issue is that the corporation seems real (not a legal fiction) and that it (not its individual shareholders) owns its capital and productive assets. The company possesses an independence, a separateness, and an existential reality: it is not a fiction, social institution, or political power.

Shareholders, members of the board of directors (BOD), and senior executives see their allegiance and fiduciary duties directly connected to the entity itself, not to some special interest group (such as shareholders). Corporate members understand a broad, impartial, and balanced set of objectives for the corporation. Similarly, management seeks to balance "the interests of [all] the parties that are directly involved in the business, including employees, suppliers and customers as well as shareholders…. to ensure that the company act[s] as a 'good citizen' or in a way that is 'socially responsible'" (Parkinson, 2003: 493).

Such attitudes—which recognize the instrumental nature of the corporate entity and a more expansive range of corporate objectives—might be prevalent in small- and medium-sized ventures or in family businesses that have incorporated to limit personal liability. The corporate entity is legally distinct and separate from shareholders; nevertheless, it represents them, reflects them, and was created (in a sense) in their image. Such attitudes and considerations might also be present among shareholders and corporate members of closely held corporations with a small shareholder base: the corporation is distinct and separate, but there is a strong sense of relatedness (Cui et al., 2018; Maldonado-Erazo et al., 2020; Su et al., 2022).

This distinct but related sentiment regarding the corporation may have been recognized by Henry Ford in 1917, when he was sued by his shareholders for reinvesting profits and failing to pay dividends. Ford recognized their objection but considered it shortsighted. The corporation (not Ford) had the best long-term interest of shareholders at heart. He explained that the role of the company, with which he strongly and personally identified, was to "do as much as possible for *everybody* concerned…. to make money and use it, give employment, and send out the car where the people can use it … and *incidentally* to make money" (Lewis, 1976: 100, emphasis added). He

lost the legal battle and subsequent appeal. In 1920, Ford bought out existing shareholders, reorganized the company, and invited only his immediate family members to become shareholders.

4 Corporate Understandings: Economic Entity or Political Entity?

Initially, the legal entity resembles the mythical Golem of Prague: its protections, potentials, and affordances are still metaphorical clay. The corporation needs to be activated, to be given a breath of life. Life comes to the corporation in two stages: (a) shareholders contribute their capital and assets; and (b) it is populated by corporate members, who provide it with direction, purpose, and action. Significantly, as the empty corporate shell is populated it is transformed from an inanimate legal entity to a social collective—an emergent community that will come to possess its own social dynamics, structures of power, and consolidating culture (Deakin, 2017; Lawson, 2016, 2017).

The populated and operating corporation retains its legal characteristics but its nature becomes more complexed and more difficult to define. New factors, dynamics, and relationships all add nuance and complexity, making simple classifications and unambiguous ontological statements difficult. As Bratton eloquently writes, "firms are bundles of unruly phenomena. They entail not just production, but production by groups of people. Therefore, theories designed to contain and regularize the appearance of firms go beyond concepts about economic production to articulate concepts about communities" (1989: 407).

Some legal scholars—focusing on its legal independence, the contractual relationships into which it enters, and the prevailing backdrop of agency theory—construed the corporation as an insubstantial and ethereal creature that hovers in a *nexus of contracts*. For these scholars, the corporation is an intangible and ephemeral space—a meeting point for a "mass of contracts which various individuals have voluntarily entered into for their mutual benefit… [the firm] is incapable of having social or moral obligations much in the same way that inanimate objects are incapable of having these obligations" (Fischel, 1982: 1273).

Others see the corporation in a more robust and substantial way: an economic vehicle, a social agent, or a political player. The nexus of contracts perspective is legally nuanced, curiously impersonal, and ignores the broader aspects of human agency and relationships. The corporation, from this understanding, is peculiarly static and distant; however, "the point that the firm is a nexus of contracts is merely an assertion or a legal conclusion…. in literary terms, the point is a metaphor" (Bratton, 1989: 410).

Given the limitations of the nexus of contracts conceptualization, there is a developing recognition among contemporary scholars—legal, social, and management—that the corporation is "a 'structure' which gives rise to power relationships… that

management dominates the structure by organizing subordinated factors of production… [and] that management owes its position to its organizational expertise" (Bratton, 1989: 414).

4.1 Corporations Understood as Economic Entities

Perhaps the most familiar construction of the corporation is as an economic entity that operates and engages in an economic world. This is the use to which the legal vehicle is most frequently put. Its legal affordances provide a way of engaging in that economic world in a ways that are more efficient and less risky. In this conceptualization, it is the shareholders—rather than a nominally fictitious legal entity—who are privileged and whose interest are served.

The corporation comes into existence through a legal process. Initially, it is a vacuous entity veiled off and separated from the rest of the social world. The created space is populated by the designated agents of the shareholders. Once the corporation is populated and activated, those who manage it engage in economic activity for the benefit of the shareholders. In this process three relational tensions come into existence:

(a) **The agency problem**. Economic engagement and activity is delegated to a managerial class who, as fiduciary agents, are required to serve the best interests of the shareholders. Those best interests are generally understood as profit maximization, wealth creation, and wealth accumulation. Determining what constitute shareholder "best interests" is entrusted to senior management. Senior management is also responsible for securing and delivering these best interests. Senior management, as intermediaries, might also engage in ventures that will enrich shareholders but which will also be beneficial for management. Considerations of personal advantage, benefit, and self-enrichment encourage management to act in their own self-interests. This is likely—realistically, it is inevitable—in a system that lacks transparency, focuses only on final outcomes, and where senior management and shareholders possess asymmetrical information and opportunities (Coase, 1937, 1991; Fontrodona & Sison, 2006).

Distanced from the immediate scrutiny and lacking direct shareholders control, corporate members may resort to "'satisfice' performance and/or engage in their own vanity, job-securing, or empire-building projects…. [where] managers lack sufficient inducement to safeguard and maximize the interests attributed to shareholders summons the specter of an 'agency problem'" (Veldman & Willmott, 2013: para. 19).

(b) **Dyadic ownership and operating relationship**. As an economic entity, the corporation demonstrates the difference between shareholder ownership of productive assets and senior management's control of them. Ownership and

control of assets are not completely separated: if they were, the corporation could neither function nor exist. Rather, a balanced relationship between ownership/control, shareholder/manager, and principal/agent develops within the corporation. It is this relationship that binds the corporation together and allows it to function. The relationship is founded on trust, mutual reliance, and a degree of reciprocity between shareholders and senior management.

Shareholders and corporate members are placed in opposition, occupying the only two sides that exist in the corporation: one exists only because of the other. For the corporation to exist—for it to function and be successful—all of its constituent members need to recognize and acknowledge "that the principal-agent relationship is at heart a dyadic (one to one) relationship" (Smallman, 2004: 80).

(c) **Dyadic internal and external environments**. The dyadic nature of corporate governance and operation creates a bipolar relationship between shareholders and corporate members. As Veldman and Willmott put it, this "leads to a dyadic view of corporate governance in which parties other than investors, directors, and executive officers are largely external to this conception of the corporation and its governance" (2013: para. 21). This duality is reflected in law, where only transactions between "investors and managers—or more accurately investors, directors, and officers—are regarded as comprising the field of corporate governance law. Other parties, however important their contributions to the flourishing of dynamic enterprise, are regarded as secondary, instrumental participants" (Johnson, 2012: 1160).

In a parallel way, dyadic polarization shapes the perception of the environments within which the corporation exists and operates. The corporation develops an *inside*—an interiority or internal environment—occupied by the interests, concerns, and advancement of the firm. In opposition to this internal space, the corporation recognizes an *outside*—the world beyond the imagined boundaries of the corporation's internal space. The corporation occupies its interior space, concerned with self-interest and self-preservation. It ventures into the external world—indeed, it must venture into that world—but it does so only if it can utilize or exploit it in ways that are advantageous.

Interiority and externality co-exist in a relational tension, but an inward focus is dominant. With reference to the internal world of the corporation, *externalities*—in both a literal and economic sense—are recognized, but "externalities are only internalised where internalisation aligns with, or is expected to improve, corporate financial performance" (Johnston et al., 2021: 39).

The economic manifestation of the corporation is one with which most people are familiar: corporations are economic players. In contemporary society, corporations are ubiquitous and often financially powerful. In most countries they are the largest contributor to national GDP. They are the major provider of goods and services; the major provider of employment and income. Few might understand or have an interest in the legal characteristics of corporations; however, everyone is aware of the activities and impacts of corporations as economic entities (Manyika et al., 2021; Shaanan, 2010).

4.2 Corporations Understood as Political Entities

There is another way of making sense of corporations. When people observe corporate behavior they see demonstrations of power and privilege. They begin to make sense of the corporation in terms of specialness—of favor and a special license—that allows them to behave in ways and achieve results different from other economic actors. In this understanding the emergence, evolution, and continuing performance of corporations are recognized to be "shifts in power relations between classes, and their respective capacities for mobilizing resources to consolidate or transform relations of domination in which elites systematically gain material and symbolic advantage" (Veldman & Willmott, 2013: para. 28).

The corporate form affords advantages and privileges to shareholders, providing them with limited liability. The corporation creates an asymmetric risk scenario in which there are potential winners and losers: shareholders are more likely to win; creditors are more likely to lose. Corporations are free to exercise a power and a privilege not granted to their creditors. The asymmetric imbalance has its expression in economic and financial terms, but its source lies in the advantageous economic power that the corporation has been granted by the state.

The corporate vehicle was designed and state-sanctioned to provide advantage for that class of capitalists who sought to increase wealth. It provided a reliable vehicle for accumulating wealth and for protecting it against the claims of others. The corporation became the preferred way of doing business and of engaging in markets. As wealth was further concentrated into the hands of shareholders, the disparity between this class and other social classes increased. The corporation served as a mechanism for perpetuating and deepening the class divide. It also served as an instrument for advancing and privileging the class who contrived it.

The corporation creates a dyadic relationship between shareholders and management, a relationship predicated on agency theory and fiscal accountability. Within neoliberal economic environments it is axiomatic that corporations are managed for the exclusive benefit of shareholders. Legalists might object on principle, but in the economic world shareholder supremacy prevails.

The agency problem posed by management is a persistent issue, gradually reduced but not totally eliminated. The degree of discretion and autonomy "enjoyed by corporate management in the post-War years was reigned [reined] in by the imposition of performance measures, notably variants of shareholder value metrics, as the tiller of economic development passed from corporate managers and state bureaucrats to the rentiers" (Veldman & Willmott, 2013: para. 35).

The corporation is an effective and efficient way of engaging in the economic world. However, its creation and subsequent development do not rest primarily on the efficiency and expertise of senior management. From a political understanding of the modern corporation it might be thought of as "more the product of the growing political power of the rentier investors than it was of economic imperatives, an argument that might easily be extended to the current attempts to universalize corporate law in its resolutely shareholder-oriented Anglo-American form" (Ireland, 2010: 838).

Understanding corporations as political entities rests on two interlocking premises: (a) corporations are self-governing, possess many of the attributes and characteristics of government, and have a subsidiary right to pursuit profit; and (b) corporations come into existence not through private contracts, but through an exercise of governmental prerogative or franchise (Ciepley, 2013).

From this perspective, the corporation can be understood as a "form of constitutional republic—a shareholder republic—with a similar governance structure and comparable range of powers" (Ciepley, 2013: 140). From the same perspective, corporations possess a high degree of ambiguity and inherent contradictions. Although their form and powers are delegated by the state, "they are run on private initiative…. [and] transgress all the basic divides that structure liberal treatments of law, economics, and politics: government/market, state/society, privilege/equality, status/contract, as well as liberalism's master dichotomy of public/private" (Ciepley, 2013: 140).

In the economic construction, the corporation is populated by those whose objective is to manage the corporation and engage in economic activities for the benefit of the shareholders. However, as a political entity within society, the corporation *additionally* recognizes and responds to the claims of other *stakeholders*—that is any individual or group that "can affect or is affected by the achievement of an organisation's objectives" (Freeman, 1984: 46).

In recognizing stakeholder interests and shareholder interests, three relational tensions come into existence:

(a) **Dyadic director and stakeholder relationship**. Directors are primarily concerned with the interest of shareholders, but they are also capable of recognizing the legitimate and counter-balancing claims of those who are involved with the corporation, who are impacted by it, and who wish to have a say in its behavior. Stakeholders—suppliers, employees, communities, etc.—are recognized as separate, authentic political groupings in the environment within which the corporation operates (Laplume et al., 2008). They need to be considered and engaged with, perhaps not as equals but as fellow citizens in the political realm.

The emergence of large, multi-national corporations with economic powers comparable to those of nations "has brought awareness that these private-sector institutions have impacts on human lives comparable to the impacts of political governments, and hence should … assume responsibility for the welfare of those over whom they wield power" (Markley & Harman, 1982: 58).

(b) **Dyadic operating and governance perspectives**. The primary perspective of senior corporate management is increasing profit and shareholder wealth. In doing so, management operates the corporation in ways that capitalize on short- and medium-term opportunities: picking the most appealing and reachable low-lying fruits. Focusing on short-term opportunities is advantageous because it tends to reduce risk, increase immediate profits, demonstrate management's acumen, and deliver higher performance-based remuneration and bonuses for management. Short-term perspectives may also be favored by shareholders

since, for publicly traded corporations, share value is based on projections of future earnings—typically for the next two or three years.

From a political construction of the corporations, those with a non-managerial outlook recognize that the long-term success of the entity requires alignment and accommodation with groups, interests, and objectives that lie beyond the entity. A tension may well result between those concerned with the day-to-day operating objectives of the corporation and those focused on its long-term strategic directions and impacts. Those involved in corporate governance need to appreciate the dyadic relationship that directors have with management. Management recognizes the necessity of oversight, strategic guidance, and the prioritization of long-terms objectives, but they may see them as hindrances and impediments. A tension between the visions and priorities of management and directors is inevitable (Guthrie, 2017).

(c) **Dyadic internal and external environments**. Senior management sees an internal corporate world that is, to a great extent, divorced and separated from the external world in which the corporation operates. Those inclined to construct the corporation from a political understanding also recognize internal and external worlds, but for them the worlds are not irreconcilably separate: they must be functionally aligned or effectively bridged. The external world is not simply one of operations: it is a world in which the corporation exists, acts, and responds. The corporation is a citizen of the society within which it is embedded and the "great growth of corporations in size, market power, and impact on society has naturally brought with it a commensurate growth in responsibilities; in a democratic society, power sooner or later begets equivalent accountability" (CED, 1971: 21).

It is anticipated that directors will recognize an implied citizenship, the corporation's power, and the necessity of being accountable to an external world (Mason & Simmons, 2014). It is also expected that they will be challenged to: (a) optimize shareholder value while acknowledging the claims of society and other stakeholders; (b) move towards a boundary-less global corporation while recognizing different national and cultural difference; (c) engage in opportunistic risk-taking while maintaining tight financial control; and (d) avoid operational micro-management while not becoming distant from, or oblivious to, those operations (Steger & Amann, 2008: 23).

Understanding corporations as economic entities is perhaps more natural for those who are employed by them or who manage them. The economic understanding seems to be more congruent with insider experiences and perspectives. In contrast, recognizing the corporation as a political entity may make more sense for those who are external to it, impacted by its activities, and who experience it as a powerful but distanced reality in their lives.

5 Corporate Navigation: Managerial and Governance Perspectives

Behavior is informed by our constructions of meaning. Those who see the spoon as an elegantly designed and carefully crafted piece of metal will admire its aesthetics and reflect on its beauty. Those who see the spoon and appreciate its affordances will understand it as an effective utensil for consuming food and will presumably utilize it for that purpose. Both understandings are appropriate, both are correct. The different resulting behaviors make perfect sense from the individual's perspective and understanding.

Other constructions of meaning are possible—whether about spoons or corporations—and different behaviors might be observed, but all subsequent behaviors and expectations, whatever they might be, are guided by the personal sense-making and interpretative processes in which we engage, and the conclusions and determinations at which we arrive (Kyriakidou, 2011; Maines, 2000).

What, then, are the implications for individual behavior when corporations are understood as either economic or political entities?

At the outset, it is important to keep in mind that no attempt is made to assume that a specific understanding of the corporation matches a specific perspective: causal relationships are not inferred. Rather, we speculate on the different outlooks and behaviors that might logically be associated with economic and political constructions of the corporation. Clear-cut lines of distinction are unlikely; instead, there is more probable that there will be an intertwining of different behaviors—just as the legal, economic, and political understanding of the corporation are themselves "intertwined to the effect that they often mutually reinforce and contradict one another" (Veldman & Willmott, 2013: para. 3),

5.1 The Managerial Perspective

Corporations can become extraordinarily powerful and successful. A recent McKinsey Global Institute paper estimated that approximately 70% of the GDP in OECD countries is generated by corporate business. Corporations form a relatively small proportion of all business ventures, yet they create a disproportionately large volume of goods, services, and employment. Many of the largest US corporations have annual revenues—and some even annual net incomes—that are larger than the GDPs of small nation states (Manyika et al., 2021).

Part of the success of the corporate venture is that they are profit-driven. Corporate members—senior management and the BOD—are required to focus on *doing the best* for the shareholder. Senior management identifies and pursues profit maximizing strategies, knowing that their actions are being monitored and that managerial success will be recognized and rewarded, and managerial failure will be punished.

Oversight is partial and imperfect, but it is recognized and accepted by senior management: profit-maximizing motivates. Personal considerations are always present, but these are restrained—if not completely eliminated—for the greater benefit of the shareholder (Khurana, 2007).

Perceived as a purely economic player in an economic game, it is not hard to understand why the corporation finds the notion of caring for the well-being of those outside its boundaries perplexing. Caring for the environment, the poor, and the disenfranchised are laudable human aspirations, but the corporation is neither a natural person nor a moral agent.

In contexts where shareholder profits and interests are prioritized, senior management will be indifferent to economic claims from an external world unless responding to them provides some corporate advantage. Likewise, developing relationships with external groups or recognizing their stakeholder status, will be viewed through a prism of opportunity and not of obligation.

Sandra Waddock, in her comprehensive work on the evolution of corporate social responsibility (CSR), defines it as a "subset of corporate responsibilities that deals with a company's voluntary/discretionary relationships with its societal and community stakeholders…. frequently operationalized as community relations, philanthropic, multisector collaboration, or volunteer activities…. the discretionary and ethical responsibilities of business" (2004: 10).

The notion of CSR does not fit easily or comfortably with the perceived purpose, goals, and behavior of the economic corporation. Corporate responsibilities do not extend to the externalized world, and it seems audacious to suggest that such responsibilities should be "manifested in the strategies and operating practices that a company develops in operationalizing its relationships with and impacts on the wellbeing of all of its key stakeholders and the natural environment" (Glavas & Kelley, 2014: 171).

The marginalizing of CSR—perhaps of rejecting it outright—tends to resonate with senior management, who understand the corporation in economic terms. This understanding was encapsulated by economist and Nobel laureate Milton Friedman who, after noting that CSR was "a fundamentally subversive doctrine in a free society", wrote that, "there is one and only one social responsibility of business …. to use its resources and engage in activities designed to increase its profits, so long as it [the business] stays within the rules of the game, which is to say, engages in open and free competition without deception or fraud" (1970: 17).

5.2 The Governance Perspective

Those charged with corporate governance are nominated and voted into place by shareholders. Directors are usually non-executive, that is they play no direct part in the operations of the corporation. The BOD often includes those who hold senior management roles in the corporation (executive directors) and is led by the senior corporate executive. Shareholders normally have no direct access the functioning

business or to have involvement with its day-to-day operations. They entrust operational matters to competent and professional managers, relying on trust, agency status, and fiduciary duty to ensure that management operates in ways advantageous to the shareholders.

Historically, the role of directors has been one of oversight: ensuring that the fiduciary duty of management is being fulfilled in the broad interest of shareholders. Shareholders, of course, face a second agency problem when they elect the BOD. Directors are charged with protecting and ensuring the best interest of shareholders, but they—like senior managers—are themselves acting as agents and may have they own self-interests or obligations to outside groups and players. The fiduciary duty of corporate directors to shareholders is predicated on absolute loyalty: "loyalty as the avoidance of self-interested behavior, loyalty as affirmative devotion, and loyalty as being true" (Gold, 2017: 883).

Traditionally, corporate governance focuses on oversight and accountability, but increasingly there have been calls for it to also focus on the long-term navigation of the enterprise. A long-term perspective is necessary, because senior managers operate on short-term issues—partly because of operational expediency, partly because short-term outcomes are more predictable.

Those who are not themselves operational managers may better appreciate that the corporation exists within a dynamic social and political external environment. They are more likely to recognize that the corporation exists within a constellation of other entities and groupings, each of which might impact corporate behavior. They appreciate the claims of the stakeholders surrounding them: federal, state and local government; suppliers and links in their supply and distribution chains; employees and their unions; banks, financial institutions, and investors; and, more than likely the Security and Exchange Commission (SEC). These non-managerial corporate members may be more appreciative of long-term strategic decision-making.

If the corporation perceives itself to be a social creature and political actor, a positive and constructive relationship—or at least an accommodating relationship—with stakeholders is essential for its wellbeing. Some critics, responding to the reticence that many corporations show for CSR, recommend the corporation should exhibit a higher degree of corporate citizenship. They argue that many expressions of corporate citizenship are too narrow, patently instrumental, and grounded in pragmatic self-interest. In engaging with the world beyond the corporation, they advocate that corporations "take on an active role in rule-finding discourses and rule-setting processes with the intent of realizing a win–win outcome of the economic game" (Pies et al., 2009: 375).

For many, especially within the realms of economics and management, CSR was originally considered to be no more than an "*adjunct* to the revived and reinvigorated shareholder-oriented conception of the corporation, which has an appeal to both corporations and their critics" (Ireland & Pillay, 2010: 78, emphasis in original). However, over time—with a deeper awareness of the corporation as a political entity and with mounting pressure from stakeholders—many in corporate governance have come to view CSR not as an adjunct, but as a *central feature* in their governance.

So what is corporate governance about and how might corporate directors approach their task?

Cornelis de Kluyver provides a succinct and elegant answer—or at least a partial answer—when he state that US corporate governance "is best understood as the set of fiduciary and managerial responsibilities that binds a company's management, shareholders, and the board within a larger, societal context defined by legal, regulatory, competitive, economic, democratic, ethical, and other societal forces" (2013: 3).

6 Change Inevitability in Operating Environments

The corporation exists within an environment that is separated from it and relationally distant. The environment is all that exists beyond the corporation, and it is more useful to differentiate the environment into: (a) an *operating* or task environment within which the corporation will do business; and (b) a *remote* or distant environment with which the corporation will not interact directly and of which it will have little or no knowledge.

The operating environment is the one that the corporation enters—a world of people (consumers, employees, and suppliers), markets, and competitors. In the past, these external environments were often geographically close to the corporation, which gave the corporation the opportunity to become acquainted with them. In contemporary business, operating environments are increasingly distanced spatially, socially, and culturally—as with multinational corporations and e-commerce.

Operating environments are dynamic and not hermetically sealed from the broader environments within which they are nested. They are shaped by factors that seem more distant, but which are pervasive: social, economic, political, and legal systems.

Operating environments are exogenous: created separately, existing independently, and possessing their own qualities and dynamics. The corporation does not create its operating environment: optimally, it tries to select one in which it believes it will be successful. The corporation cannot, in any significant or meaningful way, change or control the external environment. Nevertheless, through its efforts—marketing, public relations, political lobbying, and public affairs activities—the corporation can often moderate, or modify, the environment within which it operates.

Corporate political efforts are leveraged in situations where legislators, as in the US Congress, can own and trade in the share of companies that are impacted by their legislation (Hill & Painter, 2011). Influencing efforts are designed to eliminate potential threats, buffer the corporation from such threats, or form bridges between the corporation and perceived environmental opportunities (Meznar & Nigh, 1995). Corporate actions and behavior—both economic operations and CSR engagement—can also be used to span the perceived distances and boundaries between the corporation and those in these external environments (Brehmer et al., 2018).

6.1 Boundary Scanning

Corporations cannot significantly change their external environment, but they cannot survive—and certainly cannot flourish or prosper—unless they *understand* those environment. This is the context within which goods and services are produced and sold. This is the context within which markets exist and market relationships develop. This is the context within which shareholder value is created, captured, or destroyed. This is ultimately the context within which corporations survive or perish. Management needs to understand those with whom the entity engages and it needs to appreciate the context in which this engagement occurs. In short, it is fundamental that those who manage the corporation "understand the variety and characteristics of the external environment and forces relevant to policy formulation and decision making" (Morden, 1993: 29).

Boundaries are created when the corporation is envisaged as a separate and defined entity operating in the separate and defined world beyond it. An imperceptible boundary delimits and defines the corporate sphere, but it also separates the entity from the external environment within which it operates. Boundary scanning involves making excursions into that external environment, attempting to gain a better understanding of its nature, and recognizing how it is changing. Boundary scanning facilitates the flow of understanding, information, and intelligence (in the military sense) from the operating environment—knowledge and information that will be useful in optimizing corporate operations.

A corporation that sells women's wearing apparel sends it merchandizers to different cities to spend the weekend. Their task is to observe what people are wearing, what colors and styles are in vogue, what is being sold in the competitors' outlets, and how local women recognize and adapt to changes in fashion. The corporation operates stores in more than a dozen U.S. states. The collected intelligence is disseminated among other merchandisers and will inform purchasing decisions and inventory shipped to stores within the relevant region.

Boundary scanning represents one way of trying to understand and make sense of the external environment. That better understanding can then be viewed in a number of different ways. It can be regarded as: (a) interesting but inconsequential and not acted upon; (b) representing a temporary and transitory shift and used to make short-range tactical decisions; or (c) signaling a significant shift or permanent change in the environment and used, in part, to formulate a long-term strategic response.

Irrespective of subsequent action, boundary scanning represents the first and necessary step in what has been termed *corporate foresight* (Costanzo, 2004; Marinković et al., 2022). Corporate foresight is an approach utilized "by an organization to advance itself; that is, to fulfill its purpose and achieve success on whatever terms it defines such success" (Gordon et al., 2020: 1). Awareness of, and responsiveness to, the operating environment is crucial for the successful corporation. As a forward-thinking management philosophy, corporate foresight involves "identifying, observing and interpreting factors that induce change, determining possible organization-specific implications, and triggering appropriate organizational responses" (Rohrbeck et al., 2015: 2).

6.2 Change and Time Horizons

If the sales of the company's air conditioners fall, market analysis may determine that this is connected to the rising price of energy faced by potential customers. If the energy trends seem to be short-term and transitory, marketing and promotional tactics might be able to revive sales. If the trend looks long-term and permanent, the company may look to its R&D and production capabilities to create a new air conditioning unit that is more energy efficient: a strategic initiative. The nature of the response, should there be one, will depend on the foresight of management and on the time horizon of the environmental changes.

If, in an era when photographs are taken on film, the corporation invents a digital camera it might not be appreciated that this invention could revolutionize the photographic experience. The corporation might fail to recognize the revolutionary or disruptive potential of this new technology, routinely file a patent to protect their R&D investment, and then quietly ignore digital cameras. Is this a classic case of marketing myopia? Is it a case of the corporation's inability to envisage a new business model? Is it a preservation of the status quo and a reluctance to recognize opportunities that are too distance, remote, and risky? The truth is that this scenario can be explained by each of these reasons. Each explanation seems eminently reasonable and yet, with hindsight, each is insufficient. Perhaps the central problem was that the business simply failed to consider any of these questions and remained rooted in the present without considering the future. For this particular corporation their "Kodak moment" came in 2012 when, in a world where everyone had abandoned photographic film, they were forced to file for bankruptcy (Anthony, 2016).

The corporation acts in the present and will hopefully continue to act in the future. However, the future will not materialize unless present actions allow the corporation to survive. With present and future in mind, management turns to *strategy*—moving towards the fulfillment of a vision of the future.

- Chandler considered that strategy was "the determination of the basic, long-term goals and objectives of an enterprise and the adoption of courses of action and the allocation of resources necessary for those goals" (1962: 13).
- Mintzberg (1987), uncomfortable with the notion of a single definition, advised that strategy is better appreciated from multiple directions and in multiple ways. Strategy can take the form of a plan, a pattern, a perspective, and a position. Occasionally, strategy can also be a ploy—a maneuver that helps an organization to avoid its competitors.
- Mintzberg would later warn about the ways in which planning was confused and conflated with strategy: "*strategic planning* is not *strategic thinking*. Indeed, strategic planning often spoils strategic thinking, causing managers to confuse real visions with the manipulation of numbers…. Successful strategies are visions, not plans" (1994: 107, emphasis in original).

Senior management must have a vision of what the corporation will be and what it will do in the future. The vision may be inspired, refreshingly creative, passionately

held, and convincingly communicated. However, the vision must also be tempered by pragmatism and realism. Visions can challenge and demand reconceptualization, but visions must also allow for a satisfactory fit between what the corporation is, or can be, and its changing operating environment. Corporations can only survive, succeed, and prosper if they are aligned with their future worlds. This presents an ever-more challenging puzzle, because it is essentially impossible to predict and make sense of a world that is changing at an exponential rate.

Consequently, management tends to focus on closer visions that are more akin to the present, rather than on distant and uncertain ones in the future. Their strategic visions will be for the next few years, not decades. For good reasons—some might say for self-interested reasons—senior managers look for short-term problems that can be resolved with short-term solutions and expediencies. In doing so, they either avoid or fail to recognize problems that are long-term in nature. The question is which corporate members will deal with them?

7 Guiding Corporations into Unsettled Futures

It is all too easy to frame corporate governance exclusively in terms of agency theory, checks and balances, accountability, and increased transparency. A sad and ongoing litany of corporate greed, malfeasance, reckless risk-taking, and catastrophic failure has drawn attention to the need for more effective corporate governance and the dangers that arise when it is lacking. Ineffective governance has always been a problem in the corporate landscape, but it was brought into sharp focus and public scrutiny during the financial crisis of 2007–2008 (Bruner, 2018; Erkens et al., 2012; Kirkpatrick, 2009).

Effective governance begins by addressing the causes and manifestations of the problematic issues such as agency, operational mismanagement, and the assumption of excessive risk. But we believe that corporate governance is more than compliance and broader than accountability. While financial and accounting transparency is certainly a prerequisite, governance also needs to provide the corporation with strategic guidance and to challenge managerial decision-making about the corporation's vision, mission, and future. Instituting good and meaningful systems of governance requires a different mindset, and it "is necessary to look to sources other than narrow economic efficiency, influence and power over people and resources, and profit at the expense of society and the environment" (Dempsey, 2013: 11).

The following suggestions might be considered in transforming corporate governance into a better and more meaningful system of guiding corporations into increasingly complex and unsettled futures.

(a) **Emphasis on the future, not present or past**. Traditionally the BOD has been concerned with what the corporation has done and what it is doing. In an increasingly complex and volatile world the paramount importance is corporate survival, and corporate survival and growth should emerge as one of the

primary responsibilities of the BOD. This requires a change of perspective, a shift in priority, and the cultivation of a forward-orientated mindset. This is not to suggest that what the BOD presently does—centered on compliance, accountability, and transparency—is unimportant or that it can be dispensed with. These functions remain and will continue to remain crucial, but the scope of the BOD's work needs to be widened and directed towards the future.

(b) **Diversity of thought and understanding**. For some time it has been argued that increased diversity in BODs is a necessary element in making corporate governance more effective. From a social justice and contemporary cultural perspective, this can be interpreted as bringing greater representation, equity, and inclusion into the corporate sphere. In purely instrumental and pragmatic terms, however, higher levels of diversity and inclusion provide a mechanism for creating a BOD that has a richer source of ideas, perspectives, and experiences. Increasing diversity among BOD membership provides a different vision and a challenging voice for a wider range of stakeholders and members of society who are impacted by corporate actions and behaviors (Goyal et al., 2019; Nielsen & Huse, 2010).

Difference exists in the ways in which individuals construct their meaning of the corporation. Utilizing that difference, in the form of BOD member diversity, is regarded as a critical element in improving and refocusing corporate governance. But what constitutes diversity?

In the broad, group diversity means heterogeneity of composition, but it is also characterized by inclusion, acceptance, and valuing of difference. Diversity can be represented in two forms: (a) *surface level*, which focuses on observable demographic difference such as gender, ethnicity, age etc.; and (b) *deep level*, which focuses on unseen psychological difference such as attitudes, aspirations, perspectives, personality, etc.

Both forms of diversity can be beneficial in situations where creativity and thoughtful decision-making are involved, but deep level diversity seems to produce greater long-term group synergy and more well-reasoned decision-making (Harrison et al., 2002; Larson, 2007). Initially, the introduction of difference into teams, such as the BOD, poses problems; however, in the long-term—and if the group is carefully managed through its various stages of development—groups with deep diversity tend to be more collaborative, creative, resilient, and open to novel perspectives (Duchek et al., 2020; Lurdes & Franco, 2022).

The deep level diversity advocated here for the BOD centers around difference in perspectives, conceptualizations, and mental constructions of the corporation. A key expression of diversity should be in terms of those who conceptualize corporations as either economic or political entities. The BOD should reflect these two constructions of corporate function evenly and should not have a bias or leaning towards either managerial or non-managerial conceptualizations.

(c) **Adequate and relevant training**. Those who become members of the BOD need to know something about the operations, behaviors, and actions of the

corporation. Directors may have familiarity, even expertise, with other corporations and industries; however, this knowledge may not be transferable to the present corporation. Indeed, there is a great danger of having a significant number of independent members of the BOD selected from a particular industry. Specific and narrow insight has it value, but it reduces deep level diversity. Directors should be acquainted with the day-to-day operations, challenges, and managerial decision-making processes of the corporation (Allaire & Firsirotu, 2003).

The aim of such educational or training programs should be to provide the new directors with a deep and situated understanding of the operational context of the corporation. These educational programs will differ significantly in scope and emphasis from managerial training initiatives. Learning about the corporation and governance is an ongoing process. Increasingly, BOD are utilizing regular retreats to enhance their understanding of the business and to consolidate productive relational links with other BOD members.

(d) **Deep scanning of operational boundaries**. In operating the corporation, management continuously scans the boundaries of the external environment within which the business operates. Scanning can detect environmental changes, opportunities, or threats that will assist strategic formulation. The BOD should independently be engaged in deep scanning of the external environment—long-term, distant, and possible changes that might impact the corporation's future.

Understanding and monitoring external environments is an imperative for the BOD, but it is always problematic and it inevitably carries a degree of risk. Even the most diligent and intelligent scanning cannot identify every change that will provide future opportunities or pose future threats. Changes may be overlooked, misinterpreted, or given too much or too little weight. The obvious reality is that opportunities and threats in the external environment can only be definitively recognized *after* the event.

Further, predicting causal relationships between external change and the corporate operations is tentative at best. Extrapolating into an unseen and unknown future presents the strategic analyst with insurmountable difficulties, even although there may be an operational urgency to detect potential opportunities or threats—or at least to provide a probabilistic assessment of their likelihood. From both due diligence and corporate insight perspectives, BOD environment analysis is imperative. Granted, the effectiveness and reliability of such analyses will be challenging; nevertheless, deep boundary scanning should be set as a key function of the BOD (Wheelen & Hunger, 2010).

(e) **Concern for stakeholders and shareholders**. Issues of CSR and a concern for the interests of corporate stakeholders is something that the BOD should accentuate in their guiding role. Whatever the legal and economic position of CSR, the BOD needs to appreciate that in a more politicized world—and certainly in a world where there is increasing concern, not to say irrational panic about environmental issues—many look towards the corporate world to provide a sense of direction or to develop solutions. As part of its deep boundary

scanning, pressing political and social issues need to be identified. Depending on their analysis, and in the light of the most reliable fact-based evidence, the BOD should consider whether it is reasonable, prudent, or expeditious to respond.

Although the concerns and interest of stakeholders should be accentuated, the BOD should be careful, thoughtful, and deliberate in the nature of corporate responses. They should bear in mind that public perceptions are important but that the core value of the BOD is to serve shareholders diligently and faithfully. In doing so, the BOD will need to evaluate possible responses and determine their likely impact on the long-term increase of shareholder wealth, shareholder welfare, and social welfare (Hart & Zingales, 2017; Jones & Felps, 2013).

(f) **Guidance not omnipotence**. A future-oriented BOD should recognize and accept the responsibility to direct the corporation in an optimal trajectory that provides future benefit and value for shareholders. This places a heavy burden on the BOD and they will require knowledge, understanding, insight, and fortitude to do their work. However, their role is one of guiding, not of dictating or imposing. They should appreciate that the future is unknowable and that projections, predictions, and possibilities are required, but that these speculative efforts might do little more than provide a sense of security in an uncertain world.

At best, the BOD is a knowledgeable guide and a competent navigator, but the future external environment remains uncharted and the corporation's destination is unknown. Of necessity, a collective sense of humility is required—a quality that may productively differentiate the BOD in many corporations from their senior management (De Clercq et al., 2021; Toscano et al., 2018).

8 Conclusion

The corporation has been accurately described as one of the most successful inventions in history, an entirely new creature, and an expression of the political power and influence of the financial property owning class. These descriptions serve to underscore the multiple ways in which the corporation is perceived and its behavior is understood. From it legal creation more than a millennium ago, the corporation has been recognized as different from other economic and political entities, possessing attributes and affordances that set it apart from the society within which it exists and functions.

The corporation is distanced by veils and shields that it has been uniquely granted by the state. It recognizes its own separated nature, distinguishing between internal and external environments. Of necessity, it engages with a world that lies beyond it and yet, while present in that world, it is not included in it. This separation is recognized by those within the corporation and by those who observe it from the outside. It is suggested that these different perspectives result in and reinforce how people construct meaning regarding the corporation. Some, particularly those within

the corporate world, see it as a legal or economic entity; outsiders, who are impacted by corporate behavior, tend to see it as a political entity.

Constructions of understanding and meaning both have a strong influence on future courses of action and behavior. Corporate management is likely to shape their future—and more importantly the future of the corporation—predominantly in terms of economic expediency and the unique affordances provided by the corporate form. Management tends to focus on short-term threats and opportunities that they recognize in their external environment. Their analysis, decision-making, and strategy may be perfectly executed and successful in the short-term. However, they may be limited by their perspective and not look towards, or recognize, long-term issues.

In a world that is increasingly economically, politically, and socially turbulent, it is inevitable that change—sometimes abrupt and disruptive—will arise in the corporates external environment. Attempts to predict such abrupt shifts and disruptive events are limited; however, diligence and future-orientated thinking cannot be suspended because of these limitations. The corporate BOD should recognize that future-orientated boundary scanning is imperative and that it may provide a necessary route for ensuring, if not guaranteeing, the corporation's survival. Further, many of the more distance threats and opportunities involve social and political dimensions that might not concern or engage upper level management. These issues might be seen as too distant, too unpredictable, or fail to make an impact on those who are inclined to see corporations in economic and legal terms, rather than in social or political ones.

In the ongoing growth and evolution of corporations, the BOD needs to exert a different kind of control. Its present statutory duties and efforts to ensure accountability and transparency need to remain; indeed, they might have to increase in the future. But the new direction of the BOD and of corporate governance lies in a concern with the future, rather than the past. It requires the BOD to accept the realities of significant change in the future and to have in place the mechanisms to recognize and respond to such change.

In doing so, directors need to forge a close working relationship with senior management—a relationship that is open, accepting, and dedicated to the overarching wellbeing of the corporation and its shareholders. A key part of appropriate and successful governance lies is the ability of the BOD to be flexible in their understanding of the nature, purpose, and future of the corporation as a strange and successful innovation, but also as a creation that has not become—and perhaps can never become—a recognized citizen of its society. To that goal, the BOD should encourage, promote, and enshrine diversity of thought regarding the corporation among its members.

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Governance Principles for Sustainable Urban Tourism and Climate Transition

Iryna Chernysh, Jan T. Frecè, and Deane L. Harder

Abstract In this chapter, we will try to bring together concepts and principles of governance for corporations, tourism, and climate transition, with a focus on urban contexts. First, governance in tourism will be introduced in general and subsequently related to main stakeholder clusters and their dynamics and biases. Second, we will briefly discuss the conceptual shift from sustainability to sustainable tourism, detailing how tourism is part of sustainable development and relates to corporate sustainability as well as highlighting some links between urban development and climate change from a tourism perspective. Third, we exemplify some concepts that are influential on an international level in the further development of urban tourism like 'post-smart cities' and 'wise cities'. Based on these analyses and examples, we will examine normative aspects of governance structures and principles that we will use as a foundation to put forward some policy recommendations for the future development of governance in tourism to mitigate the negative impacts of climate transition and generate and capture value for relevant stakeholders as part of a sustainable development.

Keywords Sustainable tourism · Climate transition · Governance · Urban tourism · Wise cities

1 Introduction

In this chapter, we will try to bring together concepts and principles of governance for corporations, tourism, and climate transition, with a focus on urban contexts. First, governance in tourism will be introduced in general and subsequently related to main stakeholder clusters and their dynamics and biases. Second, we will briefly discuss the conceptual shift from sustainability to sustainable tourism, detailing how

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tourism is part of sustainable development and relates to corporate sustainability as well as highlighting some links between urban development and climate change from a tourism perspective. Third, we exemplify some concepts that are influential on an international level in the further development of urban tourism like 'post-smart cities' and 'wise cities'. Based on these analyses and examples, we will examine normative aspects of governance structures and principles that we will use as a foundation to put forward some policy recommendations for the future development of governance in tourism to mitigate the negative impacts of climate transition and generate and capture value for relevant stakeholders as part of a sustainable development.

1.1 Governance and Tourism

Governance can be defined as "a process whereby societies or organizations make their important decisions, determine whom they involve in the process and how they render account" (Graham et al., 2003). Planning, development, and design are the most crucial parts of governance, especially in tourism: inter-relationships of tourism sector actors are an essential condition for competitive tourism destinations development, considering sustainability principles and Climate Transition (UNWTO, 2022c). Efforts to structure tourism planning, development, and design on different levels go back to the 1970s, pointing to significant changes that needed to be done (Gunn, 2014; Sessa, 1976). In the 1990s, the first sustainable tourism development community started their activities, and in the 2000s, governance principles and structures started to be implemented in the tourism industry (Bono i Gispert & Clavé, 2020; Borges et al., 2014). The United Nation World Tourism Organization (UNWTO) was formed in 1975 to provide guidance and share successful practices and policies on national, regional, and local levels. Thus, in 2008, UNWTO provided a descriptive definition of tourism governance as "the process of managing tourist destinations through synergistic and coordinated efforts by governments, at different levels and in different capacities; civil society living in the inbound tourism communities, and the business sector connected with the operation of the tourism system" (World Tourism Organization, 2019). Obviously, the need for governance in tourism has been recognised and structures are well-established; however, the link to global change is often not well-defined or visible enough.

In order to tackle the challenges of climate change, appropriate governance principles need to be implemented in all industries. The tourism industry is responsible for significant impacts globally, due to its total volume and exponential growth (The World Counts, 2022). Further growth in the consumption of tourism is often heralded with positive implications but comes at a high price. On the one hand, it is one of the fastest growing sectors of economics in the world that is the key driver of social and economic progress (UNWTO, 2020c), with its economic and employment benefits, not just in tourism but in many related sectors (Fankhauser et al., 2018). On the other hand, with the projection of 1.8 billion international tourist arrivals by

2030, its impact includes the exhaustion of local natural resources through over-consumption, pollution, lack of waste management, etc., and an increase of 25% in CO_2 emissions from tourism is expected, raising from 1.6 million tons in 2016 to 2.0 million tons by 2030 (The World Counts, 2022). The Global Code of Ethics for Tourism (UNWTO, 2020a) was implemented by UNWTO as one of the most significant instruments in achieving the Sustainable Development Goals (SDGs). Sustainability, social inclusion, and building trust through business performance are vital principles contributing to social, economic, and environmental integrity. This integrity should be implemented on all governance levels and by all the main actors. A successful governance system is, therefore, meant to direct the achievement of the core purpose and mechanism for achieving SDGs (ISO, 2022).

Challenges in organizational governance differ and depend on business culture, industry, country, etc. Often, organizational governance faces more challenges in less developed countries (Transparency.org, 2022; World Bank, 2019) because of a lack of relevant laws, regulations, standards to follow, etc. In the case of tourism, general governance standards can be used as a base and adapted to the specifications of companies and other relevant stakeholders. International standards like ISO 37000:2021 on the *Governance of Organizations* provide wide-spread sets of tools and governance templates for the implementation of responsible, sustainable governance principles, developed for all countries, all sectors, all types, and all stakeholders (ISO, 2021). The main reason for compliance with this standard, or at least the basic recommendations, is optimizing all possible benefits for all types of stakeholders, including long-term goals of social and environmental systems, such as mitigation of climate change risks. Therefore, suitable governance structures are readily available but need to be tailored to the topic of climate change and customized for stakeholders in different regions and fields in the tourism industry, and will be discussed in the following with a focus on urban tourism as cities are key players in the tourism system.

Climate change highlights the necessity of guidelines and principles to deal with the complexity of urban tourism governance, including new opportunities and benefits of climate transition. Lately, urban tourism had to face additional types of risks, such as COVID-19, economic sanctions, war, and other problems that require new management tools and resources to respond effectively. Governance principles in the tourism industry mean not just company or governmental-level management mechanisms; it has broader aspects—such as planet governance, thus strong partnership of all types of stakeholders is crucial. The implementation of governance structures in tourism commonly pivots on the principle of creating partnerships and tourism communities. Thus, it is not enough to just consider corporate governance; public and private collaboration is essential as climate change risks affect a range of systems and spheres of actors and stakeholders in the industry. Responses of governance systems on different levels need to include policies that will help adapt urban tourism to climate change through key sustainability principles (Lopes et al., 2021, 2022; Organization and Forum, 2019; Scott et al., 2019). Furthermore, effective governance in tourism needs to include the main characteristics of good governance (ISO, 2021) like effective performance, responsible stewardship, or ethical behaviour. To this

Fig. 1 Smart governance in tourism principles. Illustration by authors, adapted from Huete (2018)

avail, relevant stakeholders should participate and be closely connected in policy- and decision-making processes to make the adoption of measures more likely, and improve sustainability and competitiveness indicators of tourism destinations.

Apart from sustainability, the main driving factors for tourism governance are accessibility, innovation, and technology, fueling the demand for 'smart' governance. Smart governance in tourism should include aspects like ensuring liquidity and job protection, assuring safety and security, public-private collaboration, responsibility, and harmonisation while using protocols, standards, and procedures, jobs' added value through new technologies, innovation, and sustainability as new normality. Establishing public-private partnerships for adopting these principles was stressed by the UNWTO in its 2020 "Global Guidelines to Restart Tourism" report (UNWTO, 2020b). The implementation of the combination of these governance factors at tourist destinations should, subsequently, be geared toward the mitigation of climate change while covering all the aspects of 'smart' governance (Fig. 1) (Huete, 2018).

1.2 Stakeholders

An urban context is a complex social system and has a multitude of stakeholders. In the context of sustainable urban tourism, there are three stakeholder clusters: industry, government, and community (Timur & Getz, 2008). Potential conflicts arise in the areas of overlapping interests (Fig. 2); however, these areas may also hold the potential for innovations as a form of creative solutions to underlying conflicts of interest. Ultimately, initiatives for sustainable tourism will occur in the sweet spot in the center of the model, in the 'triangle of conflicts and innovations', if different interests can be harmonised between the major stakeholder clusters.

Fig. 2 The main stakeholder clusters of the system of 'sustainable tourism'. Illustration by authors

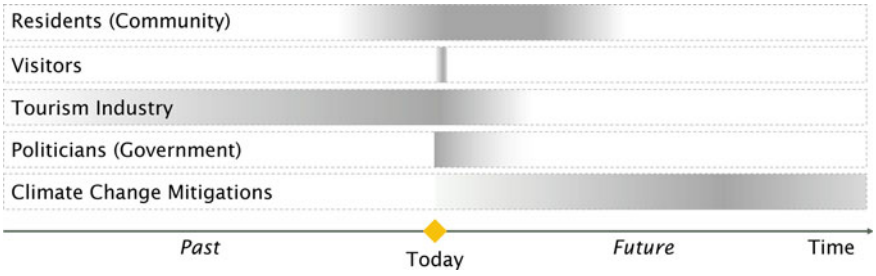

Fig. 3 A schematic representation of the time horizon and focus of interest over time for different stakeholder groups and potential climate change mitigations. Although generic, it is clear that conflicts of interest may arise from these differences that should be considered in governance principles for sustainable urban tourism. Illustration by authors

Sustainable development has a strong element of time. Looking at the main stakeholder groups and their interests in temporal aspects of urban tourism, it is clear that there are divergent perspectives (Fig. 3). Residents have a certain awareness of the past and also look into the future; however, these perceptions are mostly restricted to a few years and do not consider long-term effects. Visitors usually have an even more restricted time window they consider, often limited to planning a stay and the actual time spent in an urban area. The tourism industry has developed its business models on the existing assets of an urban environment, in most cases built on past developments like historical buildings or museums. Politicians have the moral mandate to secure the livelihood of a community today and in the future but many office-holders are

predominantly concerned about the present and their perception of time is commonly governed by electoral cycles. In contrast, climate change mitigations are needed now but hopefully will increase their effectiveness over time, which will further their perceived importance by the general public. Considering the temporal aspects of sustainable development and accounting for the typical window of time of interest in urban tourism of stakeholder clusters, specific subgroups of stakeholders can be identified, i.e., the tourism industry, present and future host community, present and future visitors, and politicians or decision-makers who allocate the limited resources available to mitigate the detrimental effects of climate change in an urban context (Byrd, 2007).

Previous research has underscored the role and importance of stakeholders as a core component of sustainable tourism. It has been shown that 'stakeholder involvement' facilitates the implementation of sustainable tourism (Waligo et al., 2013). This might also improve the perception of the quality of life of community residents not involved in tourism (Woo et al., 2018). Moreover, the management of the stakeholder involvement process is vital to stimulate co-design for the enhancement and management of touristically attractive sites and offers (Della Spina & Giorno, 2021). This can be implemented as community-based development of tourism but often, public-private partnerships are required (George et al., 2007). At least with ecotourism, the role of so-called 'extension agents' who serve as educators on responsible tourism topics and facilitate partnerships between government, businesses, local residents, and visitors has been identified as a mediating factor for the successful development of touristic offers (Feyers et al., 2019). What is missing is a comprehensive analysis of the contextual and individual factors as well as approaches to ensure multi-stakeholder perspectives conducive to the development of such offers in an urban context, with a special focus on climate transition.

1.3 Dynamics and Biases

Sustainable tourism encompasses ecological, social, and economic aspects. When specifically applied to urban tourism, the concept addresses a wide range of related needs, e.g., mobility, accommodation, food, infrastructure, touristic services, etc. At the same time, sustainable tourism poses the question of what kind of impacts on an ecological, social, or economic level are considered "tolerable", which impacts are supposed to be mitigated in one form or another, and which impacts are to be rejected. Obviously, the answer to what aspects should be considered "tolerable" will be different depending on which stakeholder group is answering. Consequently, sustainable tourism cannot be considered a purely technological affair, optimising resource use and greenhouse gas emissions stemming from tourism. It is, rather, a social negotiation process, considering and harmonising the different needs and biases of different stakeholders or stakeholder groups. Naturally, the concrete stakeholder groups vary from urban setting to urban setting, but, in general, their biases

towards a specific enterprise or undertaking can be classified using the following four attitudes (LeFeuvre et al., 2016):

1. The supportive stakeholder (supports a specific goal or action)
2. The marginal stakeholder (neither highly threatening nor especially cooperative, although they have a stake in the discussion—generally not concerned about most issues)
3. The non-supportive stakeholder (high on a potential threat, but low on potential cooperation—can be the most distressing for a common goal or project)
4. The mixed blessing stakeholder (equal potential to threaten and cooperate).

Traditionally, corporate stakeholders are classified using a sectoral classification, relating to whether they consider themselves as part of the public, private or voluntary sector or a combination thereof (Jung et al., 2015; Ng et al., 2013). Mapped to an urban tourism context beyond the purely corporate perspective, this results in stakeholders groups of the following composition:

- Public stakeholders: political parties, politicians, public agencies, etc.
- Private stakeholders: tourism industry (incl sub-contractors), visitors, hosting community, residents, etc.
- Public/private stakeholders: state-supported interest groups, the research community, corporations acting on behalf of public agencies, etc.

All these stakeholder groups—including the entities populating them—stretch (potentially) across the entire spectrum from being marginal, non-supportive, or mixed, all the way to supportive. Consequently, every stakeholder has to be evaluated individually and cannot be evaluated merely based on their stakeholder group membership with regard to the support dimension. Research indicates that different stakeholders are acting in disparate and ambiguous processes of understanding the problem, fulfilling information needs, and exhibiting only a weak interaction between actors, available resources, and necessary tasks (Lopes et al., 2022). Moreover, there are biases or specific perspectives, which are group-specific rather than stakeholder-specific since they are based on the time perspective of entire groups of stakeholders. Figure 3 illustrates the different time perspectives of a few prominent stakeholder groups with regard to tourism, e.g., while the tourist industry's focus is primarily on the past, building on collected data and experience in order to make their relatively short-term plans, climate mitigation actors focus on long-term considerations and change, and are, therefore, not equally interested to build on the past.

From a purely economic point of view, conventional touristic offers are commonly cheaper to develop and deliver than more sustainable ones. Issues in developing and diffusing sustainable urban touristic offers arise because providing offers that are more sustainable than conventional offers often entails non-mainstream solutions that may not be as cost-efficient in their development and delivery. Bridging the gap between climate change mitigation and sustainable urban tourist offers requires innovative approaches. The perceptions of 'sustainability' might not be embraced yet by all relevant stakeholders and the whole concept of sustainable touristic urban offers may not be perceived as important and beneficial to the local population and other stakeholders. It is therefore important to create a balanced view of proposed

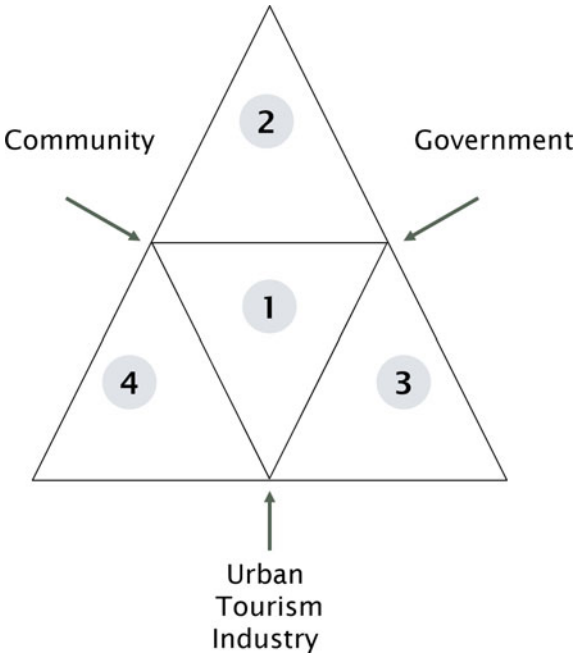

Fig. 4 The 'triangle of conflicts and innovations' with driving forces from different stakeholder clusters. Illustration by authors

measures, considering the different perspectives and timelines of stakeholders, e.g., by using a cost-benefit matrix with differentiated weighting for different stakeholders or their representatives (Fig. 4). The use of these such tools, however, should be based on specific guidelines and principles. Subsequently, we will identify successful initiatives and derive design principles that can be applied in other tourist and urban contexts.

2 From Sustainability to Sustainable Tourism

The principle of sustainability is a crucial element of all aspects of human civilization, including its environmental and socio-economic systems. Sustainability is probably one of the most important and widely used political and managerial concepts across different political or corporate levels (Abad-Segura et al., 2019; Johnson & Schaltegger, 2016; Kern et al., 2019). Its principles remain the same regardless of whether sustainability is implemented in the context of sustainable development, e.g. as part of a regional or national policy or in an organization or corporation as part of an organizational or corporate policy. In both cases, sustainability is focused on long-term observation, discussion, and regulation of human beings, their behaviour, and their impact on the world and each other considering environmental sustainability, economic sustainability, and social sustainability. Even if sustainable development

and corporate sustainability share basic ideas, however, these two topics must be considered separately to do justice to their dissimilarity and mutual dependence in regard to sustainable tourism.

2.1 Tourism and Sustainable Development

According to the United Nations specialized agency of the World Tourism Organization (UNWTO), sustainability principles refer to tourism development's environmental, economic, and socio-cultural aspects (UNWTO, 2016a). Following sustainability's multidimensional approach, a balance must be achieved between these three dimensions to foster long-term sustainable development in tourism (United Nations Environment Program, 2005, 11–12). Subsequently, the UNWTO posits the following definition, "sustainable tourism development meets the needs of the present tourists and host regions while protecting and enhancing opportunities for the future. It is envisaged as leading to management of all resources in such a way that economic, social, and aesthetic needs can be fulfilled while maintaining cultural integrity, essential ecology processes, biological diversity, and life support systems" (UNWTO, 1998, 21).

In recent decades, tourism development has become significantly dependent on the main global trends (Eckert & Pechlaner, 2019; García-Madurga et al., 2019). The concept of sustainable development of tourist destinations has become one of the mainstreams of the implementation of the goals of sustainable development announced by the UN: targets in Goals 8, 12, and 14 (United Nations, 2016)—inclusive and sustainable economic growth, sustainable consumption and production (SCP) and the sustainable use of oceans and marine resources, respectively (UNWTO, 2016b). Recognizing the importance of developing "sustainable tourism", the central management and governance tools aim to market and promote it. In turn, this increases tourist flows and, as a result, has a detrimental effect on certain ecologically- and socially-sensitive tourist destinations (Hall et al., 2017). Thus, the preservation of vulnerable touristic assets is often left without appropriate attention—no governance principles have been developed that would encourage the transition to a more holistic and sustainable approach. A governance structure for tourism development, therefore, has to be developed with the overall goal in mind of achieving and maintaining such a balance of sustainability dimensions. Although such a governance structure for tourism development undisputedly has a great influence on sustainability-related decisions within corporations affected by it, it is material to realize the difference in perspectives when it comes to sustainable tourism.

On a policy level, the sustainability of tourism development is often perceived as a positive factor in the development of regions, societies, and even a global society (UNEP, 2022). The tourism sector is directly or indirectly related to approximately 53 industries, so sustainable development of touristic products and services will frequently entail synergistic effects and encourages sustainable developments in

neighboring and linked sectors (UNWTO, 2022b). Sustainable tourism development, according to the UNWTO, should result in "tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment, and host communities" (UNWTO, 2022a). While this definition covers a broad topical range when referring to "current and future economic, social and environmental impacts", its focus gets considerably narrower when naming relevant actors and their needs, "[the] visitors, the industry, the environment, and host communities".

While the economic and environmental dimensions are covered quite broadly by naming "the industry" and "the environment", the social dimension is handled with more specificity by explicitly naming "visitors" and "hosting communities". This approach limits the social dimension to the area affected by sustainable tourism development, while the remaining two are left unconfined. It may seem intuitive to address these specific groups of people when drafting a concept for sustainable tourism development. Since sustainable tourism development is, however, only one of several parts of sustainable development, omitting all societal stakeholders outside touristic areas does not come without its issues, especially with regard to the principle of social inclusion (World Bank, 2022) or more specifically the approach of sustainability and social sustainability of tourism.

The practice of sustainable development of tourism traditionally strives, in its ecological dimension, towards a resource and preservation-oriented use of ecological resources, supporting basic ecological processes and promoting the preservation of both natural heritage as well as the local and regional biodiversity. Its social dimension, however, is more selective and at least at times blurs the line between sustainable development and the sustainability of individual tourism providers, hotels, cabin rentals, etc., when mainly focusing on visitors and host communities. As important as these two groups of stakeholders are from a corporate sustainability perspective, they only consist of two groups out of several others from a sustainable development perspective. This becomes very clear when looking at the UNWTO's guidelines supporting the socio-cultural authenticity of local host communities, preserving their cultural heritage and traditional values, promoting intercultural exchange, and, last but not least, ensuring efficient long-term economic operations that deliver socio-economic benefits to all stakeholders that are equitably distributed, including stable employment and income opportunities and social services to host communities and contribute to the fight against poverty (UNWTO, 2022a). This begs the question of whether only the interests of the local host communities and visitors are taken into account since there are only two groups of stakeholders explicitly mentioned by the UNWTO guidelines. There are, however, other social stakeholders with stakes in national tourism, beyond the host communities and the visiting guests:

- People affected by the additional traffic caused by tourism development.
- People affected by the economic concentration in and around tourism hotspots.
- People not covered by the developed tourism offers.
- People affected by the rising price level in and around tourism hotspots.

Obviously, these goals cannot be achieved by the actions of individual players in the field but require concerted and aligned efforts by multiple stakeholders, streamlined by a common strategy (Frecè & Harder, 2018). Previous research, however, also has shown that this requirement of sustainable tourism is often not met by current and planned tourism developments, or at least insufficiently. This is in stark contrast to the global ethical code of tourism, which promotes the right of all people to equality in obtaining access to the resources of the planet, and, in turn, is the main postulate of the concept of *accessible tourism for all*. Usually, accessible tourism defines touristic products just for low-mobility groups of tourists (UNWTO, Fundacion ONCE and ENAT, 2020). It should be noted that *accessible tourism for all* involves ensuring accessibility not only for people with disabilities but also for other groups with limited mobility: people with temporary disabilities, families with small children, elderly people, etc. Taking this argument further, it is clear that 'limited mobility' may also refer to the unwillingness or inability to spend as much money as more mainstream or upmarket tourists (Song et al., 2020). Subsequently, affordability becomes a basic requirement for sustainable tourism.

Sustainable developments in the tourism industry as well as more specific products and services attract significant attention in scientific studies and have become one of the fast-growing research areas since the late 1980s (Lu & Nepal, 2009; Streimikiene et al., 2021; Zolfani et al., 2015). The UNWTO has defined sustainable tourism as "tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities" (UNWTO, 2022a). Moreover, this definition entails a strong belief that "guidelines and management practices are applicable to all forms of tourism in all types of destinations, including mass tourism and the various niche tourism segments" (United Nations Environment Program, 2005, 11–12). This highlights the need to not only make tourist offers more sustainable, but also to provide options to cater to the full spectrum of potential tourists. Therefore, a governance structure for tourism development has to be developed with the overall goal of achieving and maintaining such a balance of sustainability dimensions. Although such a governance structure for tourism development undisputedly has a great influence on sustainability-related decisions within corporations affected by it, it is necessary to realize the difference in perspectives when it comes to sustainable tourism.

2.2 Tourism and Corporate Sustainability

The definition of 'organisational sustainability' is laden with difficulties, and this entails shortcomings with the definition of the term 'sustainable tourism'. Past conceptualizations of sustainable tourism were often concerned with destination scale issues and highlight the need to properly account for the environmental and social impacts of tourism's travel phase. Addressing climate change is considered a

prerequisite to sustainable development and therefore germane to advancing sustainable tourism research. Tourism is currently considered among the economic sectors least prepared for the risks and opportunities posed by climate change and is only now developing "the capacity to advance knowledge necessary to inform business, communities and government about the issues and potential ways forward" (Scott, 2011). At the same time, more holistic approaches demand transparency along the whole supply chain of product and service providers, if possible, in line with scope 3 emissions reporting (Ducoulombier, 2021; Li et al., 2020). Therefore, the extension of 'organisational sustainability' to 'sustainable tourism' requires a framework to conceptualise the necessary elements and establish an appropriate form of governance.

The Sustainable Development Goals (SDG) aim at reorienting the tourism industry to sustainable tourism. Research indicates that there is a need to rethink human–environment relations given the mistaken belief that the exertion of more effort and greater efficiency will alone solve the problems of sustainable tourism (Hall, 2019). Community-based tourism fosters community participation by emphasising responsibility and social equity, ensuring that the implementation of new tourist offers is adapted to local needs, and providing opportunities for residents, thus contributing to socio-economic aspects of sustainability (Malek & Costa, 2015; Tolkach & King, 2015). Studies have demonstrated, however, that perceived benefits have a more significant effect on tourism sustainability than on community residents' support (López et al., 2018). On the business side, perceived self-efficacy and contextual constraints appear to be strong determinants for companies to shift toward sustainable tourism (Kornilaki et al., 2019). On the customer side, research has shown that psychosocial constructs such as attitudes, beliefs, and values might predict sustainable behaviours (Chuang et al., 2018), although there is possibly a strong component of habit (MacInnes et al., 2022), and a well-documented knowing-doing gap in the field of sustainability (Tölkes, 2020). Furthermore, "Tourists increasingly seek a unique quality in their travels and are better informed before deciding on a tourist destination to spend their holidays or leisure time. They want to have unique, memorable experiences, and because of that, they are willing to look for those destinations that can offer them something different" (Solís-Radilla et al., 2019). The tourism industry's future is hence characterised by achieving a balance between satisfying the demands of a growing number of tourists and at the same time transforming their business models into a future-proof, sustainable version of themselves.

2.3 Urban Development and Climate Change

In 2015, the Conference of Parties (COP) agreed on an international treaty on climate change. The Paris Accords focus on limiting the expected rise in temperature to well below 2 °C compared to pre-industrial levels (UNFCCC 12 December, 2015). Cities contribute significantly to global carbon emissions and might suffer considerably from the consequences of increased temperature levels (Field & Barros, 2014;

Solecki et al., 2011). Moreover, urbanized areas have the tendency to expand, and "national urban plans have the potential to foster sustainable land-use systems at the national scale, while they are less likely to foster sustainable outcomes within cities" (Schindler et al., 2018). To counteract these trends, local authorities are recognized as key players in mitigating the effects of climate change (Göpfert et al., 2019; Kern et al., 2019) and it will take multilevel coordination regarding climate policy with synchronisation of adaptation strategies in different areas (Mocca et al., 2020). The Covenant of Mayors for Climate and Energy (CoM) is an example of how local authorities are organised in supranational networks in their efforts in implementing measures of climate change mitigation. Relevant data are compiled and processed in a streamlined framework for recording, documenting, and reporting (Palermo et al., 2020). The CoM represents almost 10,000 cities and towns with more than 300 million inhabitants. The need for action to mitigate climate change, therefore, has been widely recognised and entities with various levels of formalisations have been formed. What is missing so far is a clearer link to sustainable tourism as a major driver of climate change. A sustainable urban development, therefore, has to consider both, sustainable tourism and climate change mitigation.

One widespread definition of sustainable development is 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). This definition is aimed at the connections between economic development, environmental protection, and social equity, each element reinforcing the other and with a particular focus on poverty. The World Tourism Organisation (UNWTO, 2022a) defined sustainable tourism development as 'sustainable tourism development that meets the needs of present tourists and host regions while protecting and enhancing opportunities for the future'. It emphasises the management of all resources in such a way that economic, social, and aesthetic needs can be fulfilled while maintaining cultural integrity, essential ecological processes, biological diversity, and life support systems. Although less explicit, this definition also encompasses the entirety of the market, including the 'bottom of the pyramid' of potential customers that could or should be addressed with affordable offers.

The sustainability of tourism is directly linked to the popularity of destinations. Tourist hotspots suffer from 'overtourism' like Venice or Pompeii (Ercolano et al., 2018; Hospers, 2019), resulting in negative tourist experiences (Yu & Egger, 2021) and environmental impact (Brtnický et al., 2020). At the same time, the value of less attractive or low-level excitement tourist experiences, e.g., digital detox, slow city, or social interactions with community residents (Kim et al., 2023), is still not exploited by many tourist destinations, underestimating the possibilities of emotion-based design of offers (Volo, 2021) and customer engagement (Rather, 2020), or fearing interferences with the destination's dominant brand image (Gardiner & Scott, 2018). Cities are complex entities that can be described as socio-ecological-technological systems that require combined research from natural and social science if they are to be understood and governed (Schindler et al., 2018). The supply side might have to react, however, as the generation of Millennials of European Generation Y demonstrates specific micro-trends that counteract the trend of visiting tourist

hotspots, e.g., creative tourism, off-the-beaten-track tourism, alternative accommodation, and fully digital tourism (Ketter, 2020). Based on the growing importance of Millennials in global travel, these micro-trends are reshaping supply and demand and transforming the tourism and hospitality industries. To this avail, it should be considered that tourists recognize attractiveness on four levels: context, tourist belt, complementary attractions, and nucleus (i.e., the rationale that primarily appeals to tourists, associated with the main and specific attractions found in a particular destination (Boivin & Tanguay, 2019)). As a consequence, innovative offers that are affordable and sustainable at the nucleus can contribute to an easing of touristic hotspots and provide valuable experiences to customers with non-mainstream requirements.

Research has identified a number of issues in the perception of affordable tourism (Azcárate et al., 2013; Montero, 2020). The notion of affordable tourism often is associated with cheap and low-quality offers (Caserta & Russo, 2002; Keane, 1997). This notion neglects the double-sidedness of affordability as it can mean not just the ability but also the willingness to pay. In particular in situations with a wide range of touristic offers, e.g., in an urban context, considerations of willingness to pay might be decisive in the turnover of visitors or community residents into tourist customers (Birenboim et al., 2022; Jurado-Rivas & Sánchez-Rivero, 2019). For truly sustainable development, it is necessary to provide value-generating touristic experiences for all as well as lowering the threshold for participation and customer engagement by providing tourist offers with a low price tag. Subsequently, the core value-generating experience for affordable touristic offers needs to appeal to both, the inability or unwillingness to pay.

Existing research on sustainable tourism generated a comprehensive body of knowledge that supports touristic companies and city councils in systematically developing and diffusing new and sustainable urban touristic offerings (Aall & Koens, 2019; Korez-Vide, 2013; Morrison & Maxim, 2021). The concepts of ‘smart city’ and ‘smart tourism’ extend this approach by integrating value generation by digital means (Visvizi & Troisi, 2022; Visvizi et al., 2018). “Vienna is widely recognised as an example of urban sustainability, crowned as one of the most liveable cities worldwide by several quality of life rankings. Despite being highly committed to incorporating the ecological and social dimension into its urban development strategy, Vienna is undergoing a deep transition, orienting its urban policy more closely toward economic criteria and techno-managerial solutions to climate change” (Mocca et al., 2020). Although relevant and useful, these approaches neglect the needs and desires of various customer segments, e.g., tourists with restricted mobility, looking for slow city experiences, or trying to undergo a ‘digital detox’ (Young & Lieberknecht, 2019).

The concept of sustainable tourism extends the field of conventional tourism. Accepting the premise that sustainable tourism is aimed at visiting tourists as well as community residents implies that sustainable tourism needs to be an integrated part of urban development. Having separate approaches for sustainable tourism and sustainable development of the city is neither efficient nor necessary. Especially measures to fight the detrimental effects of climate change can and should be elaborated in the context of sustainable tourism. It is essential to look at a holistic tourist experience, on the one hand, and identify multi-functional measures in line with other urban

efforts, on the other hand. Parks, trees, and vegetation in general, for example, can be managed to provide shade, and lower ambient temperatures as well as offer an attractive atmosphere for residents and tourists alike. Although not enough argument for visiting a city, it will contribute to the overall tourist experience. This big-picture view and decision-making need an appropriate framework and, subsequently, governance to balance long-term interests with short-term requirements from a variety of stakeholders. In the following section, we will adopt the perspective of some of them.

3 'Post-smart' Cities and 'Wise' Cities

Cities around the world are increasingly recognizing the importance of adopting a touristic city concept and related strategies as means of optimising sustainable environments (Bakıcı et al., 2013). This concept is based on the idea of the 'smart city' (Visvizi & Troisi, 2022) and 'smart tourism' (Gretzel et al., 2015), as least partly driven by the digital transformation and opportunities to provide a more personalised urban experience to visitors (Buhalis & Amaranggana, 2015). Particularly for cities facing emerging issues of residents' negative perceptions of tourism (Ozturk et al., 2015), the concept of a 'smart tourism city' empowers a city to rise to this challenge by creating urban spaces that residents and visitors can enjoy together (Lee et al., 2020). There is, however, a lack of evidence that becoming a 'smart city' will empower residents to participate in governance structures or forms of e-democracy in general (Hambleton, 2021).

The concept of 'smart city' has fostered a plethora of initiatives that help to advance urban tourism. Nonetheless, smart tourism research to date is found to be lacking in terms of addressing emerging ("post-smart") social issues increasingly faced by global tourism cities, such as growing inequalities between host communities and visitors (Fan et al., 2017), wellness (e.g., slow tourism and slow cities) and resilience and mental health (e.g., digital detox), among others (Young & Lieberknecht, 2019). Moreover, the concept of 'smart city' is often focused on optimizing the planning of timing and infrastructure as well as the coordination of traffic flow through information technology systems and real-time data (Young & Lieberknecht, 2019). While this might be favourable for motorised individual mobility or large masses of mainstream tourists, the long end of the distribution might get neglected, ignoring the needs and requirements of the whole spectrum of tourists visiting and community residents living in an urban area. Moreover, these concepts often fail to integrate 'old' big data of buildings and infrastructure and 'slow' real-time data that might indicate gradual structural changes to the built environment (Carrera, 2016), contributing to a 'digital twin' of the city (Shahat et al., 2021). Obviously, the full potential of the 'smart city' approach has not been realised yet, but may also benefit from a conceptual extension.

The concept of ‘smart cities’ has been very successful and is still going strong. Research has, however, found ample justification to extend this concept to ‘post-smart cities’ or ‘wise cities’. The shortcomings of the existing approaches have been recognized, e.g., by Coca-Stefaniak (2021):

> A post-smart approach to tourism city management and marketing calls for rethinking of existing tourism and urban policies that address wider sustainability issues exemplified by the urban transitions debate as well as adopting a more holistic networked approach to smartness involving entire regions. This also calls for the development of a new research agenda in urban tourism through a new prism – the post-smart ‘wise’ tourism destination.

In light of these insights, many smart tourism city research initiatives still fail to address the full spectrum of potential turistic customers (Visvizi et al., 2018) as sustainable offers are often developed with a financial premium compared to conventional offers (Gholipour et al., 2019). From a pragmatic point of view, this might be acceptable as ‘sustainability’ is still considered an extra rather than the default but it also illustrates the need for a rigorous scientific analysis of the design principles of affordable and sustainable touristic offers in urban contexts as an essential contribution to post-smart ‘wise’ tourism destinations.

The ‘smart city’ concept and digital transformation have made some tourist experiences more affordable, e.g., Uber, TripAdvisor, AirBnB, as digital tools meant a de-monetization and de-materialization of value generation (Fan et al., 2017). It can be expected that this trend will continue and digital means will facilitate the accessibility of tourist offers in general (Teles da Mota & Pickering, 2020) and can be used to promote tourist offers through user-generated content (Iglesias-Sánchez et al., 2020). Additionally, the general trend of personalization and mass customization will permeate more and more areas of society (de Bellis et al., 2019), allowing for an alignment of positive emotions and experience in recommender systems (Polignano et al., 2021), but also raising corresponding expectations in potential touristic customers (Greiner & Goh, 2021). However, these more affordable elements in the touristic value chain refer more to the organisation, administration, and value delivery rather than the core value-generating touristic experience (del Vecchio et al., 2018). Therefore, providers of digital factors in the value chain of touristic offers should be integrated as stakeholders in the development of affordable and sustainable city tourism but the focus should remain on the actual experience on-site.

Another alternative pathway of urban development beyond the ‘smart city’ concept is the Cittàslow movement. This movement was initiated in Italy, in 1999, and comprises 287 cities globally (as of 3rd quarter of 2022) (Cittàslow, 2022). It aims at preserving the unique characteristics of places, people, products, food, and the environment (Walker & Lee, 2021). Furthermore, it puts special emphasis on local or regional uniqueness, focusing on the ‘slowness of a city’ and formalised by the integration of sustainable development principles and local governance with council-communities (Presenza et al., 2015). One group of the desired impacts are actions based on an ‘alternative philosophy’, termed a form of ‘mobilization against globalization’ that characterizes development as grassroots, sustainable, equitable, and authentic (Semmens & Freeman, 2012). The resulting outcomes are considering

various aspects of urban living and are intended to improve the quality of life for residents and visitors alike (Craig & Parkins, 2006). Some of the criteria to be accepted as a member city of the movement are (Mayer & Knox, 2006; Semmens & Freeman, 2012):

1. Environmental (waste, pollution, and recycling).
2. Infrastructure (open and public space, seating, and access).
3. Urban quality (gardens/parks and historic buildings).
4. Autochthonous production (markets, local food and crafts, arts, healthy eating, and local identity).
5. Hospitality and liveability (facilities for tourists and community life).
6. Cittàslow awareness (local involvement and council-community communications).

The Cittàslow movement integrates many relevant factors of sustainable tourism but lacks a more general approach to account for digital aspects of urban development as well as allow for an integration of more physical-technical initiatives related to climate change. Therefore, sustainable tourism needs to address the 'smart city' as well as 'post-smart' city concepts and integrate climate change measures.

Following previous research on sustainability in tourism 'sustainable tourism development' concerns an economic, social, and environmental tourism development that aims at the continuous improvement of tourists' experiences (Briguglio et al., 1996; Butler, 1991; Sharpley, 2000; Vellas & Becherel, 1999; WCED, 1987). It has also been shown that the tourism industry has huge potential to contribute to sustainable development, particularly through job creation, including employment for women and marginalised groups (Cukier, 2002; Gorg, 2000), highlighting that sustainability covers all elements that constitute a complete tourism experience (Zolfani et al., 2015). The objective of sustainable tourism is to strike a balance between protecting the environment, maintaining cultural integrity, establishing social justice, promoting economic benefits, and meeting the needs of the host population in terms of improved living standards, both in the short and long term (Liu et al., 2013), in developed and emerging nations (Hall et al., 2003; Swarbrooke & Horner, 2006), while emphasising intergenerational equity and intra-generational equity (Liu et al., 2013), and in a form that can maintain its viability in an area for an indefinite period of time (Butler, 1993, 1999). In community tourism, sustainable development is applied to improve the residents' quality of life by optimising local economic benefits, protecting the natural and built environment, and providing a high-quality experience for visitors (Bramwell & Lane, 1993; McIntyre, 1993; Park & Yoon, 2009; Park et al., 2008; Stabler, 1997). According to the UN Environment Program, sustainable tourism takes full account of its current and future economic, social, and environmental impacts, addressing the needs of visitors, the industry, the environment, and host communities (UN Environment Program; UN World Tourism Organization). Moreover, it refers to the environmental, economic, and socio-cultural aspects of tourism development, and the process of finding a balance between these three dimensions must be actively managed to guarantee its long-term sustainability

(UNEP & UNWTO, 2005). In summary, sustainable tourism has to act in the context of the local population as well as provide valuable experiences for all tourists.

4 Governance for Sustainable Tourism and Climate Transition

Like every industry, tourism governs and is governed. Due to closer relationships of the tourism industry with local communities, however, the local environment, the urban context, and the social and cultural character of the surrounding, the two-sidedness of governance comes into play more strongly, creating an intrinsic need for not only sustainable governance in the tourism industry but also good, sustainable governance in the political and social context tourism takes place in.

In the past, many companies acted on the premise of profit maximisation and unlimited growth (Friedman, 1970). Obviously, this approach cannot be sustainable within the planetary boundaries (Raworth, 2017). Moreover, the damage caused by past economic and socio-political activities needs to be rectified and looming climate change risks mitigated. This situation requires measures and initiatives that are on a long time horizon and involves numbers of stakeholders beyond typical companies (Frecè & Harder, 2018; Göpfert et al., 2019). On the one hand, a corporate governance approach is too limited for this complex situation (Frecè, 2022), on the other hand, many diverse stakeholders are creating impacts in a system driven by tourism activities (Chandrakumar & McLaren, 2018; Morrison & Maxim, 2021; The World Counts, 2022). A purely economic perspective falls short of the requirements of the situation just like purely political solutions cannot be expected to be embraced by the tourism industry (Laine, 2010; Malek & Costa, 2015). It is necessary to establish governance frameworks that take into account the aspects of sustainable tourism, sustainable development, and climate transition. As this kind of framework will entail some limitations on what is doable, recommended, or socially acceptable, a normative approach is required (Therborn, 2000).

Good governance may be an ideal but certain principles that should be applied are getting broad recognition. Based on the United Nations Development Program on governance and sustainable human development (United Nations Development Programme, 1997), a set of five principles for good governance have been posited by Graham et al. (2003). (1) Legitimacy and Voice, (2) Direction, (3) Performance, (4) Accountability, and (5) Fairness. These principles can be used as a filter to identify common criteria in the plethora of governance frameworks. A study by Biswas et al. (2019) concluded with a set of 13 criteria and 74 subcriteria for a good governance framework. Applied to sustainable tourism in urban areas, most of these criteria and subcriteria can be adopted or used to develop more specific elements of a governance framework (Table 1).

Table 1 The criteria and sub-criteria of a good governance framework (Biswas et al., 2019)

Criteria	Subcriteria
Accountability	1. Regular independent audit 2. Active anti-corruption commission 3. Past financial-year accounts inspected and approved 4. On-time formal publication of contracts, tenders, budgets, and accounts
Transparency	1. Publication of municipal structure, rules, regulations, and performance standards of various services, products, etc 2. Local community leader selection through a fair process 3. Public access to government documents and information 4. Public review of budget and financial reports 5. Feedback or rating on openness and fairness 6. Availability of all the publicising mediums: information centre, public hearing, mobile app, website, bulletin, and banners
Participation	1. Participation by local leaders in local governance meeting regularly with higher attendance 2. Public forum for sharing views and information 3. Referenda and citizens' initiatives, plebiscites, and people should be aware that they can participate in local government 4. Assessing citizen outreach & their participation in local governance meetings 5. Closeness of municipality to their citizen 6. Community's monitoring level on government project implementation 7. Programs and training to facilitate the promotion of skills & knowledge 8. At least 1 civic association per 10,000 population with technical capacity
Effectiveness	1. Completion of government projects within agreed timelines 2. Timely responsiveness to complaints 3. Effectiveness at addressing public problems 4. Evaluation of municipal management, elected officials, and other public & private service providers 5. Effectiveness in policy implementation 6. Local government or authority should maintain office hours
Equality	1. Unbiased administration or political culture 2. Citizens' charter 3. Promotion of gender equality 4. Pro-poor pricing policy 5. Inclusive municipality (ethnically and socially vulnerable groups)
Vision and planning	1. Consistency between public policy, strategic and development plan 2. Vision statement with integrity which holds target and timeline 3. Rewarding good administration, as well as penalising the bad 4. Long-term private-public commitment 5. Geography and spatial features while planning

(continued)

Table 1 (continued)

Criteria	Subcriteria
Sustainability	1. Assessment of the need & possible societal impact of a project or program 2. Eco-friendly development or program or project 3. Detailed economic analysis and optimum use of funds
Legitimacy and bureaucracy	1. Citizen access to justice 2. Codes of conduct 3. Legally constituted tender board and proper tendering 4. Law enforcement by the municipality along with police & other authority 5. Citizens have the right to organize unions 6. Compliance with manpower regulations (min. wages meet standards) 7. In law disclosure of accounts & funding sources 8. Capacity of the courts to influence local politics
Civic capacity	1. Advocacy or public support or civil dialogue along with community and service providers to make informed and coordinated policies or decisions based on reliable information 2. Publicize minutes from participative body meet even with negative views 3. Civil society works and keeps communication with the private sector, the national & international community, and the media 4. Public evaluation of local representatives 5. Penalizing/rewarding local representatives through public evaluation
Service delivery	1. Active & dedicated maintenance cell 2. Public satisfaction survey on quality or level or condition of municipality services & responsive performances 3. Coverage of services and fulfillment of demand in slums & all public places 4. Facility for citizen complaints 5. 24 h service 6. Strong educational support and awareness campaign 7. Need to generate data out of feedback (especially from the public domain)
Efficient economy	1. Co-funding or incentives for entrepreneurship or any business model 2. Government budget allocation and efficient expenditure 3. Collection of associated revenues & including tax (actual & mandate) 4. Precise technical specification of the goods and services in the tender documentation 5. No contrary audit report & financial irregularities 6. Effective resource allocation, utilization, and management (including cadastre management) 7. Ease in fund transfer for approved programmes or projects 8. Regulate economies as per the need for improvement

(continued)

Table 1 (continued)

Criteria	Subcriteria
Relationship	1. Coordination level among local, regional & national administrations 2. Respect for the rules of power distribution and harmonious relationship between local, regional & national administrations 3. Existence of private organizations achieving public objectives
Security	1. Quick & active conflict resolution 2. Predefined territorial boundaries 3. Security towards land use and land tenure 4. Safe municipality especially for women, children, old, poor, activist, and other vulnerable groups 5. People feel free to express their opinion in public 6. Counselling & engagement for identified people with potential social risks

One area to be more explicit is the criterion of sustainability. The current set of subcriteria of sustainability is (1) an assessment of the need & possible societal impact of a project or program, (2) eco-friendly development or program or project, and (3) a detailed economic analysis and optimum use of funds. On a more abstract level, these subcriteria refer to the three dimensions of social, ecological, and economic impacts. Here, it might be useful to expand the list of subcriteria to be more specific and provide more guidelines regarding the impacts over time so that different initiatives can be evaluated and prioritised.

In light of the digitization of entire cities and regions, the question of data ownership and access grows in importance not only for cities but also for tourism. Data contributed by public sources, sensors, commercial services, and individuals are the foundation of not only smart city governance but also the governance of tourism offers and services. For such a data pool to function, however, rules regarding anonymisation, open data formats, and ontologies, etc. have to be agreed upon and implemented in a way, where access is as unrestrictive as possible without endangering the privacy and safety of individuals. In such a data ecosystem, where common ontologies give data meaning and access is not a privilege of few, new forms of governance, perhaps even forms of self-governance find a supporting context to grow in, for hosting communities but also for the development of new services and offers by the tourism industry.

5 Conclusion and Policy Recommendations

Tourism in general and sustainable tourism, in particular, have a closer relationship to the direct environment of the area corporations operate in than most other industries. In addition to the usual collection of stakeholders, like employees, customers, or suppliers, local communities, the local environment, the urban facilities and features,

and the social and cultural character of the surroundings play a much more important role in tourism. Therefore, when aiming for a sustainable future for this industry, balancing stakeholder needs, while transforming, in close cooperation with the urban environment and its government, towards a more distributed, less standardised, more adapted, local form of tourism is of even higher importance than in other industries. Based on this perspective and simplified to general applicability, the following policies should play a significant role in the adaptation of tourism to the requirements of the Anthropocene.

The tourism industry is a major driver of climate change. Climate transition measures are directly coupled with sustainable development and, therefore, the way tourism is developing as well. In the field of tourism, corporate sustainability means climate-responsible touristic products and services. Urban areas are a hotspot to be affected by climate transition but also offer opportunities for innovations in tourism that might be mitigating climate change. Supporting these efforts with digital means lead to the concept of 'smart cities' but some urban aspects deserve more attention, like the inclusion of 'old' data regarding immobile, static elements like buildings, streets, parks, etc., and securing open access. The digital twin of cities will be essential for urban development and sustainable tourism. Some concepts go even beyond the 'smart city' with the proclamation of a 'wise city', catering to needs and desires that can not easily be satisfied with digital enablers. Developing and offering sustainable tourism products and services is heavily supported by the services provided by smart cities. At the same time, biases due to different time horizons of fields of interest of different stakeholders can lead to potential risks of non-declared biases in algorithms of smart cities. This approach could subsequently be improved by expanding the rather technological, data-based view of a 'smart city' to the impact and sustainability-oriented view of a 'wise city'.

In the field of tourism development, strategic decisions independent of individual tourism products, services, or providers need to be taken, not only addressing climate aspects but also social aspects, e.g., avoiding overburdening of communities, landscapes, or ecosystems by tourism. Sustainable tourism should be available for as many as possible, with as little negative impact as possible; if not, it is only consumed by a few privileged individuals and cannot have any relevant influences on sustainable development. Tourist hot spots like cities should, therefore, see the need to incentivize more sustainable product and service offers of sustainable tourism to a whole range of different types of tourists. This can include services and products originally designed for the resident community, as long as it does not result in a competitive situation between residents and guests. Ideas for initiatives will mostly occur in the 'triangle of conflicts and innovations' with driving forces from different stakeholder clusters (Fig. 4). Based on their relevance over time, a ranking of initiatives can be proposed, starting with the sweet spot in the center, where 'sustainable tourism' accounts for a wide range of interests, assessed by all relevant stakeholders and adjusted by pre-defined weights.

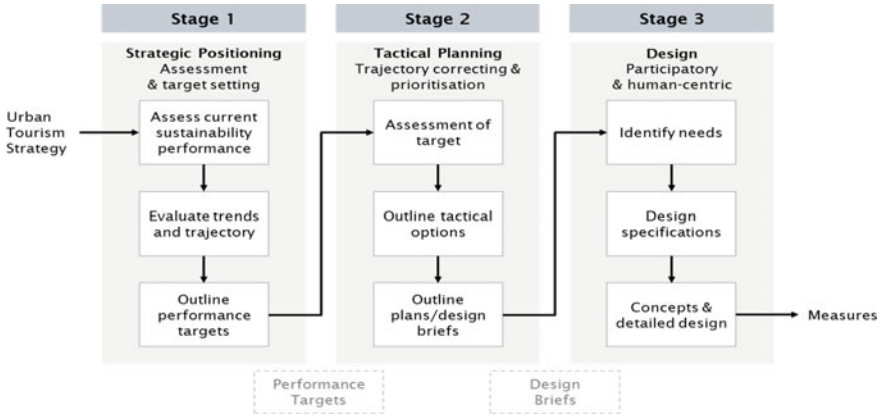

Fig. 5 Concept of a staged process to translate an urban tourism strategy into concrete measures, including performance targets and design briefs. Illustration by authors, adapted from Shin and Colwill (2017)

Urban governance requires principles of commitment of cities and towns, aligned with frameworks beyond national boundaries, e.g., Cittàslow. There can be a two-pronged approach for the development of sustainable tourism in urban areas: locations, products, and service elements are described using an open ontology and can later be used by public or commercial providers to link services, locations, products, user preferences, sustainability impact, etc. to an individualized offer, booked and paid through a single entity, starting and ending at the visitor's home, to enable an end-to-end process perspective. In addition, a balanced governance framework with community residents (local), the tourist industry, and the long-term perspective (climate) needs to be put in place, guaranteeing access, the weight of opinion, and the time perspective of various stakeholder clusters. The goal for the further development of sustainable tourism is governance, which ensures that 'smart' and 'wise' services and products always account for their negative and positive footprint on a social, ecological, and economic level, offering personalized offers based on door-to-door planning and a scope 3 accounting. This could be achieved through a multi-stage process that translates strategic positions into tactical planning and concrete design of tourist offers (Fig. 5). Ultimately, this kind of governance could help in mitigating the detrimental effects of climate change but also bring multi-dimensional value and benefits to a large spectrum of stakeholders.

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Analysis and Forecasting of Water Resources and Use in the Context of Climate Transition in Selected EU Countries

Adrian Stancu

Abstract Water is one of the key elements that support life, it is part of the human's and other species' cells. Freshwater is essential for the survival of most of the Earth's living organisms both directly as drinking water and indirectly when producing food. This chapter focuses on studying 5 freshwater indicators, namely the total renewable water resources per capita and the total water withdrawal per capita, on the one hand, and on the other hand, the agricultural water withdrawal, the industrial water withdrawal, and the municipal water withdrawal, as percent of total water withdrawal. There are 19 EU countries under analysis, which were selected according to their fulfilling at least one of the two criteria, namely whether they recorded the lowest level of the average total renewable water resources per capita in contrast to the EU's average of total renewable water resources per capita, and/or whether they registered a decreasing trend of the total renewable water resources per capita throughout the specific period of time. The period under focus varies from 1961–2019 to 1993–2019 according to data available for each country, and the forecast is established for 2020–2050. The results underline worrying situations for some states both at present and in the near and medium future.

Keywords Water resources · Water withdrawal · Freshwater · Agricultural · Industrial · Municipal · Climate transition · European Union

1 Introduction

Water is one of the four major elements of the Earth together with air, soil and rocks, and fire (magma). The Earth's total amount of water (ice, surface water, underground water, and water vapor in the air) forms the hydrosphere. Even if the human beings cannot imagine the Earth without water, we must be aware that the surface water in a liquid form is almost very rare in our solar system due to the fact that other planets

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do not offer a surface temperature between 0 °C (32 °F) and 100 °C (212 °F) which ensures the liquid state of the water (McKay & Davis, 2014; Peccerillo, 2021; Vogt, 2007).

Earth's water resources includes 97.47% salt water and 2.53% freshwater of which 68.7% in glaciers and permeant snow cover, 30.1% is the ground water, 0.86% in ground ice and permafrost, 0.26% in lakes, 0.03% in swamps, 0.04% is the atmospheric water, 0.007% in rivers, and 0.003% is the biological water. Additionally, our planet's hydrosphere is a closed system but in motion due to the hydrologic cycle, in which no water is either added or removed from the system throughout time (Kundzewicz, 2010; Petersen et al., 2021; Shiklomanov, 1993).

Nowadays, a severe issue is represented by the pollution of surface and ground freshwater which is rooted in various causes, such as: the industrialization, urbanization, population growth, plastic bags, pesticides and fertilizers used in agriculture, domestic sewage, weak water treatment systems, and others (Ali et al., 2022; Jiao, 2021; Kim et al., 2016; Lebreton et al., 2017; Lundqvist et al., 2019; Niculae et al., 2018; Paun et al., 2017).

Since 1972, when the concept of sustainable development was brought into the world public attention at the United Nations Conference on the Human Environment held in Stockholm, the member states have been focusing on investing in renewable energy sources towards a carbon-neutral economy (Matei, 2013; Panait et al., 2019; Rogers et al., 2012; Sachs, 2015; Voica et al., 2015).

In the European Union [EU], the climate transition or green transition, as a path policy for achieving the goal of climate neutrality by 2050, is stated in the European Green Deal. This document was initiated by the European Commission in December 2019 (European Council, Council of the European Union, 2022a) and the timeline of the main decisions that have been taken is continuously updated and disseminated (European Commission, 2022). On 14 July 2021, the European Commission introduced the "Fit for 55 package" whose goal is to reduce EU emissions by at least 55% by 2030 as a legal obligation (European Council, Council of the European Union, 2022c). The EU supports and finances the climate transition (European Council, Council of the European Union, 2022b). It is expected that private and public investments needed to reach the goals for 2030 amount to around €520 billion per year (European Commission, 2021).

A profusion of studies deal with the analysis and forecasting of water resources and use, each of them highlighting various aspects, as follows: the sustainable utilization of water resources in a particular city (Wang et al., 2021), the forecast of agricultural water resources demand (Yi, 2022), the prediction and analysis of water resource carrying capacity in different cities (Guo et al., 2022; Ming, 2011), the future of water resources systems analysis (Brown et al., 2015), the water security for sustainable development in the agri-food sector in different countries (Frone & Frone, 2015), the short-term water demand forecasting (Stańczyk et al., 2022), the prediction and analysis of water resources demand and consumption in a specific area (Enbeyle et al., 2022; Mumbi et al., 2022; Sharma, 2022; Wu et al., 2021), the tools used for water resources analysis, planning, and management (Bozorg-Haddad, 2021), the analysis of water resources carrying capacity (Xiaojing et al., 2022), the impact of

drought on water resources using seasonal rainfall forecasts (Brown et al., 2020), the prediction of ground water level in arid environment (Mirzavand et al., 2014).

2 Analysis and Forecasting of Water Resources and Use

2.1 Research Methodology

The analysis focuses on some of the EU member states' freshwater resources and use. At the research time (year 2022), there are 27 EU countries, i.e., Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden (European Union 2022a).

The FAO's [Food and Agriculture Organization of the United Nations] AQUASTAT database has been used for gathering data. Generally speaking, it comprises data concerning water starting 1958 until 2019 (FAO, 2022).

The Eurostat (2022a, 2022b, 2022c) database, OECD [Organisation for Economic Co-operation and Development] (2022) database and The World Bank (2022) database were not useful due to their limitations, as follows:

- For a 20-year period, the complete lack of data for countries such as Denmark, Greece, Italy, Luxembourg, and Austria, and the absence of data in some important years for Belgium, Germany, Ireland, Latvia, Lithuania, and Portugal (in the case of Eurostat database);
- The water database comprises data only for two indicators, namely water withdrawals and water treatment, and the time series is limited to 4 years, i.e. 2017–2022 (in OECD database);
- Data is not available for the only two indicators, i.e. annual freshwater withdrawals and people using safely managed drinking water services (as regards the World Bank database).

The FAO's AQUASTAT database comprises 5 groups of variables, namely: geography and population, water resources, water use, irrigation and drainage development, and environment and health. Each group includes a different number of subgroups of variables. The water resources and the water use groups consist of 5 and 4 subgroups of variables, respectively, and each subgroup embeds specific indicators (FAO, 2022). This research angles on 5 water indicators which were selected from the *total renewable water resources* and *water withdrawal by sector* subgroups of variables, i.e. (Fig. 1):

- Total renewable water resources per capita;
- Agricultural water withdrawal as % of total water withdrawal;
- Industrial water withdrawal as % of total water withdrawal;

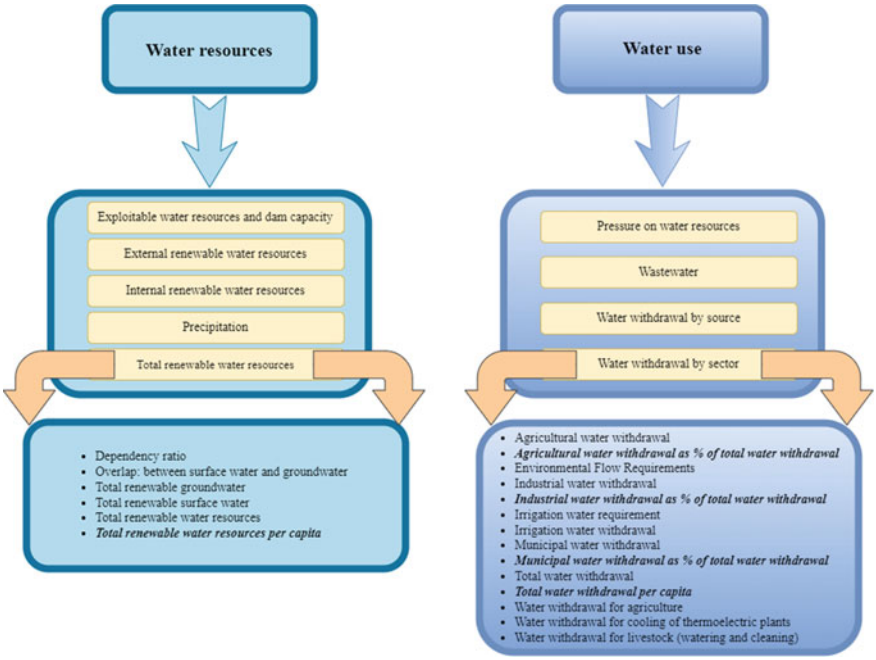

Fig. 1 Selected water indicators for analysis from the FAO's AQUASTAT database. *Source* Made by author based on FAO (2015, 2022; Margat et al., 2005)

- Municipal water withdrawal as % of total water withdrawal;
- Total water withdrawal per capita.

According to FAO, renewable water resources are represented by the freshwater resources, namely the average annual flow of the rivers on the surface and the recharge of the aquifers produced by precipitation (Margat et al., 2005).

In order to ensure the comprehensiveness and logic of the research methodology, in the case of each selected EU country, the total renewable water resources per capita and the total water withdrawal per capita are first dealt with. Secondly, the same type of analysis was carried out for the agricultural, industrial, and municipal water withdrawal as percentage of total water withdrawal (the sum of the values of these 3 indicators equals 100%). The time series for each of the five indicators contains data from 1961 (with some fluctuations among countries and type of indicators) until 2019.

The forecasting is made for 2020–2050 period, by using the Forecast Sheet tool of Microsoft Excel 2016. The confidence interval of the predicted values is 95%, as computed by the Forecast Sheet tool. Based on this value, along with the plot of the predicted values, the upper and lower confidence bounds are displayed.

Even if the predicted values are calculated until 2050 (included), in the case of the time series that starts with 1961, 1980 or 1992 year, the maximum value displayed

on the horizontal axis is 2049 instead of 2050 due to the fact that the minimum increasing unit is 3 or 4 (chosen automatically by Forecast Sheet tool according to the width of the graph set up by the user) which is used to display all the years between 1961, 1980 or 1992 and 2050. By adding 3 or 4 to 1961, 1980 or 1992, the highest number that should not exceed 2050 (the upper bound of the forecast) is 2049. This particular issue does not apply to the series that starts with 1993 for the reason that 2050 value is obtained by adding three 19 times to 1993.

Taking into account that the five indicators considered for all 27 EU member states will exceed the upper limit of the number of pages of this chapter, a criteria was required for choosing the countries that will be analyzed.

The first criterion, that was tested to be used for selecting the EU countries, was the country's level of the average total renewable water resources per capita as compared to the EU's average of total renewable water resources per capita. Each country's average total renewable water resources per capita was computed based on their both annual total renewable water resources per capita and available data (Fig. 2):

- Starting 1961 until 2019 for Austria, Belgium, Bulgaria, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxemburg, Malta, the Netherlands, Poland, Portugal, Romania, Spain, and Sweden;
- Starting 1992 until 2019 for Croatia, Estonia, Latvia, Lithuania, and Slovenia;
- Starting 1993 until 2019 for Czechia and Slovakia.

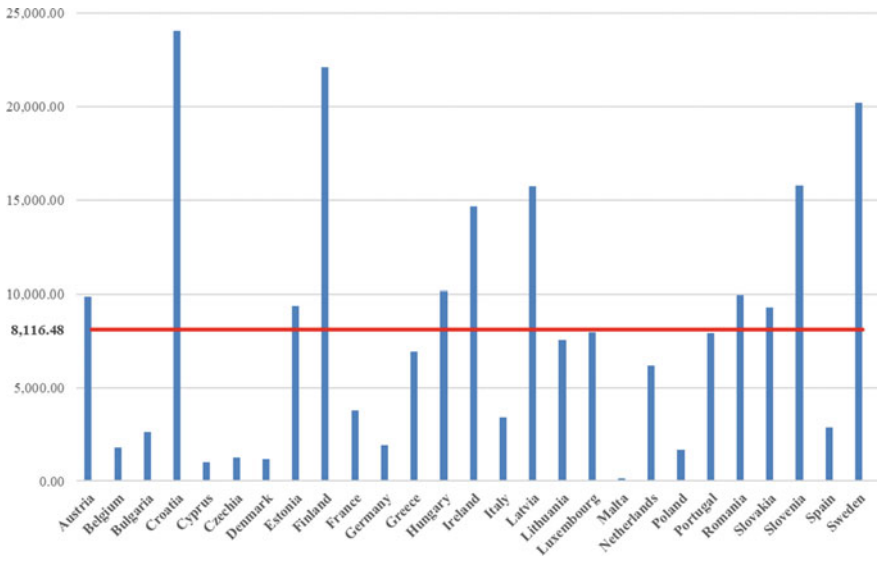

Fig. 2 Evolution of the average total renewable water resources per capita of the 27 EU member states between 1961 and 2019. *Source* Made by author based on data computed from FAO (2022) AQUASTAT database

The EU's average total renewable water resources per capita (8,166.48 m^3/inhabit/year, plotted as red line in Fig. 2) was calculated using all 27 countries' average total renewable water resources per capita. Thus, only 11 out of 27 EU member states recorded a level higher than the EU's average, namely: Austria, Croatia, Estonia, Finland, Hungary, Ireland, Latvia, Romania, Slovakia, Slovenia, and Sweden. Conversely, there are other 11 countries which registered the lowest level in contrast to the EU's average, as follows: Belgium, Bulgaria, Cyprus, Czechia, Denmark, France, Germany, Italy, Malta, Poland, and Spain.

The second criterion assessed was the EU country's evolution trend of total renewable water resources per capita between 1961 and 2019 (Fig. 3). For each country, from top to bottom, the first bar displays the total renewable water resources per capita in 1961 and the last bar plots the total renewable water resources per capita in 2019. There are similar exceptions as previously mentioned, in particular, available data starts with 1992 in the case of Croatia, Estonia, Latvia, Lithuania, and Slovenia, and with 1993 for Czechia and Slovakia.

Three evolution trends can be highlighted. The first is the increasing trend which is a positive one. It denotes a continuous rise of the total renewable water resources per capita starting with the first year of data reported until 2019, and this is the case of Croatia, Estonia, Latvia, and Lithuania. The second trend is also positive because even if the evolution recorded a decline in the middle of the analyzed period, in the last years the growths created an increasing trend. It applies to Bulgaria, Greece, Hungary, Poland, Portugal, and Romania. The third is a decreasing trend, being a negative one, due to the fact that the total renewable water resources per capita diminished constantly throughout the 1961–2019 period, and it is specific to Austria, Belgium, Cyprus, Czechia, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Malta, the Netherlands, Slovakia, Slovenia, Spain, and Sweden.

Therefore, the countries that should benefit from an in-depth analysis are those that fulfill at least one of the two criteria, i.e., they recorded the lowest level of the average total renewable water resources per capita in contrast to the EU's average of total renewable water resources per capita, and/or they registered a decreasing trend of the total renewable water resources per capita throughout their specific period of time. Thus, the following 19 countries in alphabetical order will be under focus: Austria, Belgium, Bulgaria, Cyprus, Czechia, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Malta, the Netherlands, Poland, Slovakia, Slovenia, Spain, and Sweden.

2.2 Austria

Concerning the evolution of total renewable water resources per capita between 1961 and 2019 (blue line in Fig. 4a), the analysis underlines that its level recorded a continuous decrease between two time intervals, namely: 1961–1977, and 1994–2019. The highest declines occurred in 2018 versus 2017 (−0.82%), 2019 against 2018 (−0.80%), 2017 in contrast to 2016 (−0.78%), 1994 as opposed to 1993 (−0.77%),

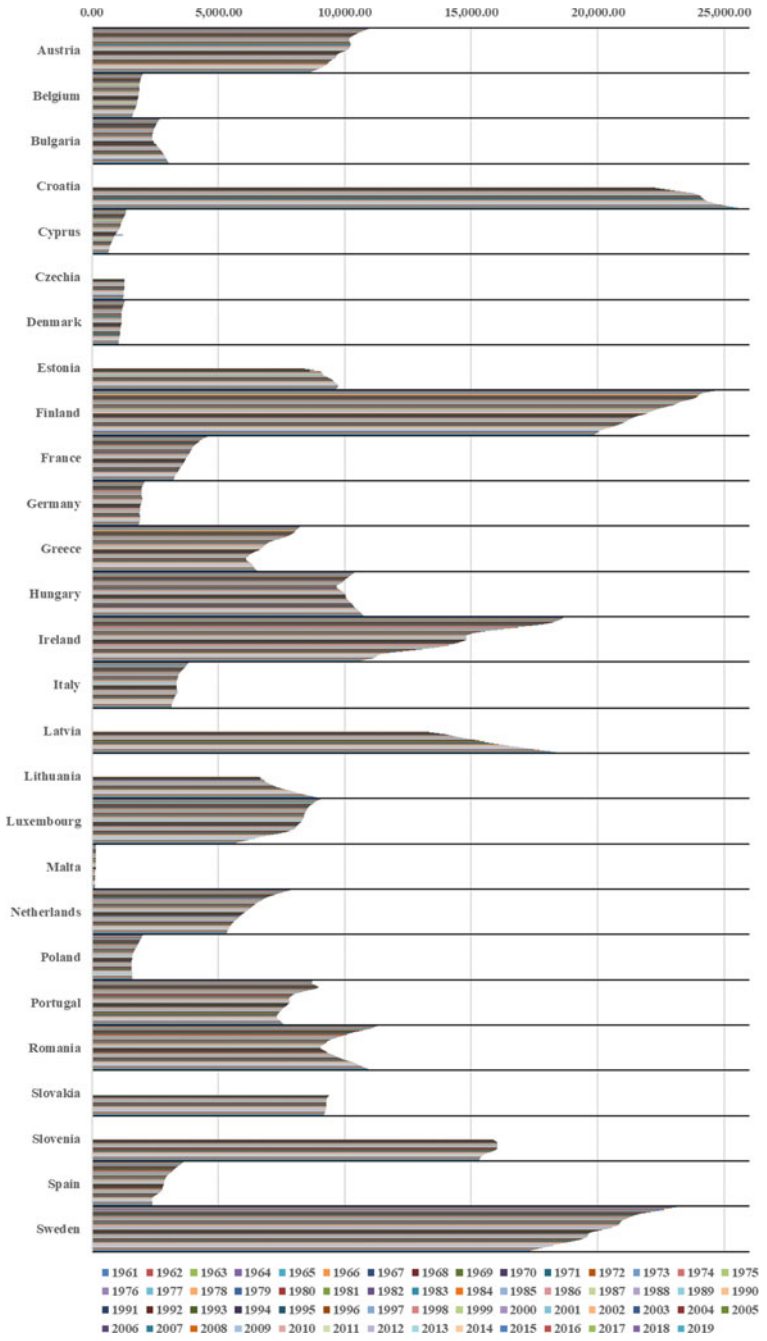

Fig. 3 Evolution trend of the total renewable water resources per capita of the 27 EU member states, between 1961 and 2019. *Source* Made by author based on FAO (2022)

and 1993 as compared to 1992 (−0.74%). Between 1978 and 1983, a rise period was registered with the highest increases in 1980 against 1979 (+0.12%), 1979 compared to 1978 (+0.11), 1981 as opposed to 1980 (+0.10%), 1982 versus 1981 (+0.06%), and 1978 in contrast to 1977 (+0.05%) (Fig. 4a).

The forecasting of the total renewable water resources per capita, between 2020 and 2050, highlights the same decreasing trend (in Fig. 4a, the red line represents the predicted evolution). Thus, knowing that the level of total renewable water resources per capita in 2019 recorded 8,676.61 m^3/inhabit/year, it is predicted to reach 7,890.12 m^3/inhabit/year by 2030, 7,178.04 m^3/inhabit/year by 2040, and 6,465.97 m^3/inhabit/year by 2050. The highest declines are estimated in 2050 against 2049 (−1.08%), 2049 as compared to 2048 (−1.07%), and 2048 versus 2047 (−1.06%). The lowest reductions are projected in 2020 as opposed to 2019 (−0.71%), 2021 in contrast to 2020 (−0.82%), and 2022 against 2021 (−0.83%).

As regards the total water withdrawal per capita between 1980 and 2019, the evolution is slightly different from the total renewable water resources per capita. Firstly, the time series has 1980 as a staring year, and, secondly, the periods with growths (1980–1990, 1996–1999, and 2009–2010) alternate with those with decreases (1991–1995, 2000–2008, and 2011–2019). The highest rise occurred in 1997 versus 1996 (+2.55%), 1996 against 1995 (+2.47%), 1981 in contrast to 1980 (+1.49%), 1982 as opposed to 1981 (+1.43%), and 1983 as compared to 1982 (+1.37%). The highest declines recorded in 1993 contrary to 1992 (−2.71%), 1994 against 1993 (−2.67%), 1992 as opposed to 1991 (−2.64%), 1995 versus 1994 (−2.55%), and 1991 in contrast to 1990 (−2.49%). Consequently, the decreasing trend of the total water withdrawal per capita is caused by the decrease ratio, which is higher as compared to the increase ratio (Fig. 4b).

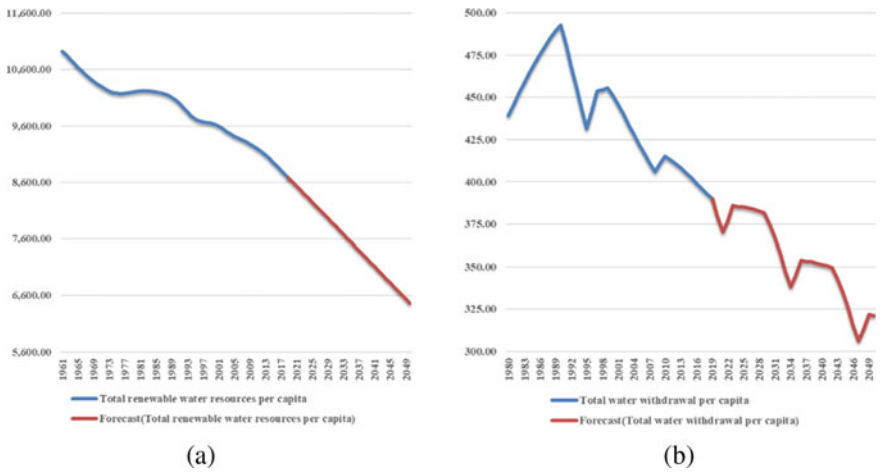

Fig. 4 Evolution and forecasting of Austria's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1980 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

The predicted evolution is characterized by the same upswing (2022–2025, 2035–2038, and 2048–2049) and downswing (2020–2021, 2026–2034, and 2039–2047) variation. The highest rises are forecasted in 2049 (+2.91%), 2036 (+2.64%), 2023 (+2.41%), 2048 (+2.07%), and 2035 (+1.87) in contrast to previous years. The highest falls are likely in 2046 (−3.27%), 2033 (−2.97%), 2045 (−2.82%), 2047 (−2.81%), and 2020 (−2.73%) against previous years (Fig. 4b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita between1980 and 2019 had a low level and it varied with a peak of 4.9% in 1990 and a base of 4.3% in 1980.

The evolution of the Austria's agricultural, industrial, and municipal water withdrawal as percent of total water withdrawal, between 1980 and 2019, highlights a similar flow of the agricultural and municipal water withdrawal as percent of total water withdrawal until 2008 concerning both growth periods (1981–1985 and 1991–1995) and fall periods (1986–1990 and 1996–2008, except 2000–2002 for the agriculture water withdrawal). The industrial water withdrawal as percent of total water withdrawal recorded an opposite evolution against the agricultural and municipal water withdrawal, whereas its level increased in 1986–1990, 1996–1999, and 2003–2008, it dropped in the other periods. Between 2010 and 2019, the weight of the agricultural, industrial, and municipal water withdrawal in the total water withdrawal levelled off (Fig. 5).

The highest spikes for the agriculture water withdrawal were in 1981 (+22.7%), 1982 (+17.99%), 1983 (+14.83%), 1984 (+12.57%), and 1985 (+10.87%), for the industrial water withdrawal in 1986 (+1.34%), 1987 (+1.29%), 1988 (+1.24%), 1989 (+1.2%), and 1990 (+1.16%), and for the municipal water withdrawal in 2009 (+7.53%), 2010 (+6.79%), 1981 (+3.92%), 1982 (+3.67%), and 1983 (+3.44%) as compared to previous years. The agriculture water withdrawal tailed off in 1990 (−17.66%), 1989 (−15.32%), 1988 (−13.57%), 1987 (−12.21%), and 1986 (−11.13%), the industrial water withdrawal in 1981 (−1.57%), in 1982 and 2009 (−1.55%), 1983 (−1.53%), in 2010 (−1.52%), and 1984 (−1.51%), and the municipal water withdrawal in 1996 (−3.1%), 1997 (−3.03%), 1986 (−1.91%), 1987 (−1.9%), and 1988 (−1.88%) against previous years (Fig. 5).

The forecast of each of the three indicators is significantly different. The predicted values of the weight of the agricultural and municipal water withdrawal in the total water withdrawal, for the 2020–2050 period, are opposite. Thus, the former are expected to follow a decreasing trend (−1.11% in 2030, −1.24% in 2040, and −1.42% in 2050), whereas the latter are projected to record an increasing trend (+0.27% in 2030, +0.26% in 2040, and +0.25% in 2050) (Fig. 5a, c). In the case of the weight of the industrial water withdrawal in the total water withdrawal, the foreseen trend is to be relatively constant compared to the value from 2010 to 2019 period (77.17%), i.e., 77.15% in 2030, 77.14% in 2040, and 77.12% in 2050 (Fig. 5b).

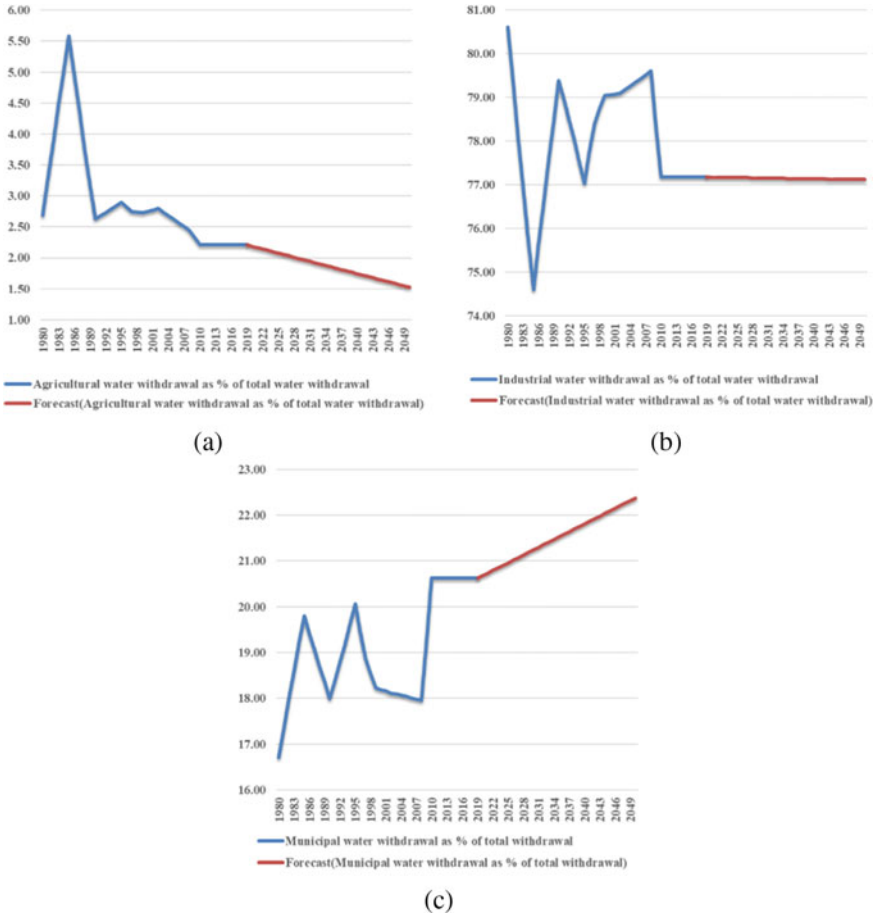

Fig. 5 Evolution and forecasting of Austria's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1980 and 2050 (%). *Source* Made by author based on FAO (2022)

2.3 Belgium

Between 1961 and 2019, Belgium's total renewable water resources per capita have fallen continuously. The highest declines were in 2008 and 2009 (−0.75%), 2010 (−0.72%), 1962 (−0.69%), 1963 (−0.67%), and 2006 and 2011 (−0.68%) as opposed to previous years. Conversely, the lowest declines were in 1983 and 1984 (−0.06%), 1982 (−0.08%), 1981 and 1985 (−0.09%), 1986 and 1987 (−0.13%), and 1980 (−0.15%) as compared to previous years. Given the level of total renewable water resources per capita in 2019 (1,585.88 m^3/inhabit/year), the forecast computed until 2050 was estimated to lower levels, such as 1,492.45 m^3/inhabit/year in 2030, 1,407.51 m^3/inhabit/year in 2040, and 1,322.58 m^3/inhabit/year in 2050. The highest

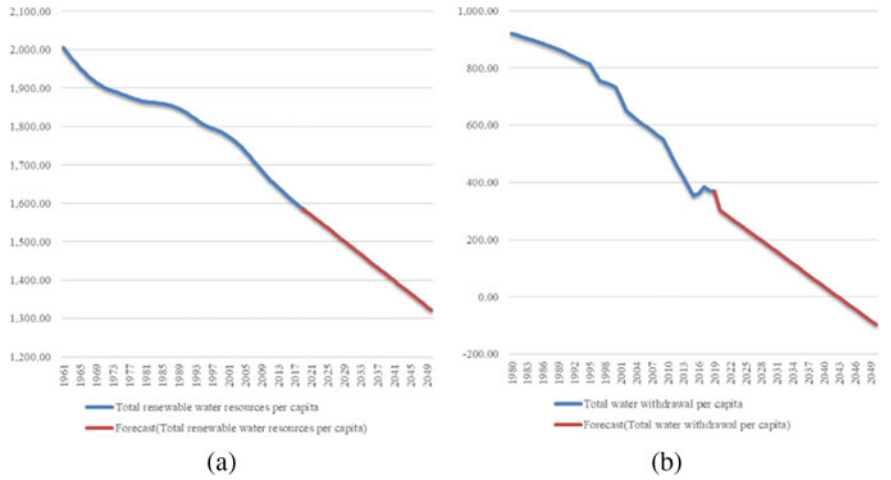

Fig. 6 Evolution and forecasting of Belgium's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1980 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

declines are estimated for the end of forecast period, such as −0.64% in 2050, −0.63% in 2047–2049, and −0.62% in 2045–2046 against previous years (Fig. 6a).

In the case of the total water withdrawal per capita between 1980 and 2019, there are only two years in which the level increased, i.e., 2017 (+5.88%) and 2016 (+2.66%) as compared to previous years. The highest diminishes were in 2015 (−7.92%), 2013 (−7.18%), 2012 (−6.91%), 2011 (−6.57%), and 2010 (−6.28%). The predicted values for 2020–2050 period highlight the decreasing trend that was recorded between 1980 and 2019. Starting with 2043 year, the level of the total water withdrawal per capita is below zero, which is unlikely to be recorded. Therefore, it is obviously that an average fall of 5% per year is realistic and, however, in 2030 the forecast level will be 170.15 m^3/inhabit/year as compared to 369.46 m^3/inhabit/year in 2019 (Fig. 6b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita between1980 and 2019 recorded a high level but it declined constantly and it halved from 49.35% in 1980 to 23.3% in 2018 and 2019, except the 2016 and 2017 year when it registered a slow growth in contrast to previous years.

The agricultural and municipal water withdrawal as percent of total water withdrawal, between 1980 and 2019, recorded approximately the same trend in which the tails off (1981–1995 and 2016–2017) alternate with rises (1996–1997, 2001–2003, 2005–2007, 2009–2015, and 2018). On the contrary, the industrial water withdrawal as percent of total water withdrawal registered boosts in 1980–1995, 1998–2000, and 2018, and diminutions in the other periods (Fig. 7).

The highest increases for the agriculture water withdrawal were in 1998 (+41.57%), 1999 (+29.76%), 2000 (+23.25%), 2018 (+22.4%), and 2015 (+21.46%), for the industrial water withdrawal in 2018 (+3.02%), 2016 (+0.76%), 1993–1995

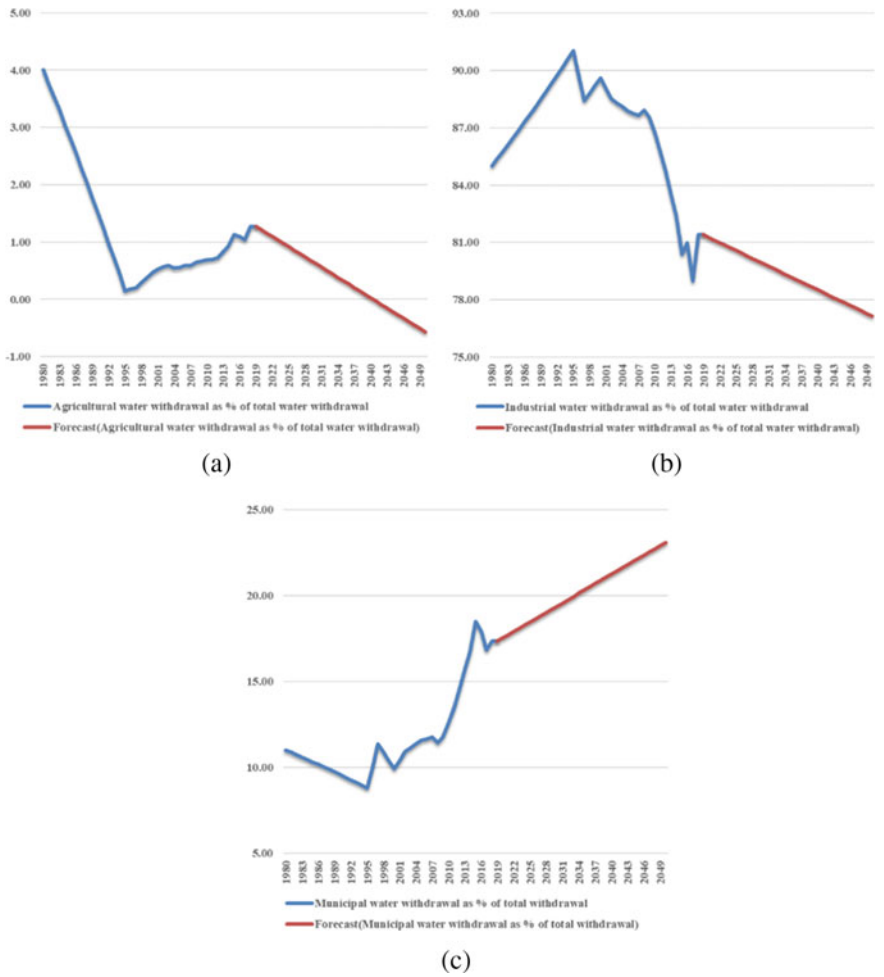

Fig. 7 Evolution and forecasting of Belgium's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1980 and 2050 (%). *Source* Made by author based on FAO (2022)

(+0.48%), 1990–1992 (+0.47%), and 1987–1989 (+0.46%), and for the municipal water withdrawal in 1996 (+14.02%), 1997 (+13.19%), 2015 (+10.66%), 2013 (+8.26%), and 2012 (+7.67%) contrary to previous years. The highest falls for the agriculture water withdrawal were in 1995 (−64.81%), 1994 (−39.03%), 1993 (−27.82%), 1992 (−21.56%), and 1991 (−17.55%), for the industrial water withdrawal in 2017 (−2.44%), 2015 (−2.41%), 2013 (−1.55%), 1997 (−1.51%), and 2014 (−1.31%), and for the municipal water withdrawal in 2017 (−6.1%), 2000 (−4.67%), 1999 (−4.1%), 1998 (−4.16%), and 2016 (−3.16%) as opposed to previous years (Fig. 7).

The weight values of the agricultural and industrial water withdrawal in the total water withdrawal expected for 2020–2050 will follow the same decreasing trend. For the weight of the agricultural water withdrawal in the total water withdrawal, the predicted values are viable until 2030 (0.62%) because beyond 2040 it will reach negative values, which is less probable to happen (Fig. 7a). In the case of weight of the industrial water withdrawal in the total water withdrawal, the estimations are 79.89% in 2030, 78.52% in 2040, and 77.15% in 2050 (Fig. 7b). As regards the weight of the municipal water withdrawal in the total water withdrawal, the predicted values describe an increasing trend, i.e. 19.38% in 2030, 21.24% in 2040, and 23.1% in 2050 (Fig. 7c).

2.4 Bulgaria

The Bulgaria's total renewable water resources per capita recorded declines between 1961 and 1985 and rises between 1986 and 2019. The highest falls were in 1962 (−0.86%), 1963 (−0.85%), 1964 (−0.82%), 1965 (−0.79%), and 1966 (−0.75%), and the highest boosts were in 1994 (+1.19%), 1993 (+1.17%), 1995 (+1.14%), 1996 (+1.05%), and 1992 (+1.02%) against previous years. Taking into account that the level of total renewable water resources per capita recorded in 2019 was 3,042.81 m^3/inhabit/year and the continuous increasing trend since 1986, the calculated forecast follows this trend and the estimated values are 3,287.45 m^3/inhabit/year (2030), 3,509.91 m^3/inhabit/year (2040), and 3,732.37 m^3/inhabit/year (2050) (Fig. 8a).

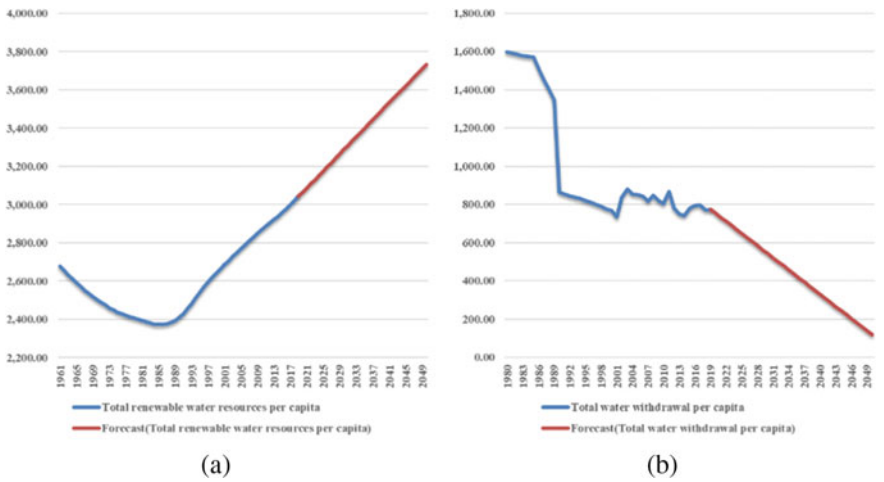

Fig. 8 Evolution and forecasting of Bulgaria's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1980 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

Speaking of the total water withdrawal per capita between 1980 and 2019, its evolution is opposed to the total renewable water resources per capita. There are only 8 years in which its level has grown and the highest expands were of +13.88% in 2002, +7.81% in 2011, +5.39% in 2015, +5.16% in 2003, and +3.6% in 2008 as compared to previous yeasts. Conversely, the highest diminishes were in 1990 (−35.9%), 2012 (−9.95%), 2001 (−4.08%), 1989 (−3.82%), and 1988 (−3.81%). The forecast of the total water withdrawal per capita shows a decline trend with values which start from 774.56 m^3/inhabit/year in 2019 to 541.76 m^3/inhabit/year in 2030, 330.12 m^3/inhabit/year in 2040, and 118.48 m^3/inhabit/year in 2050 (Fig. 8b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 1980 and 2019, declined constantly between1980 and 2019, with few exceptions in 2002–2003, 2008, and 2015–2016. The weight has fallen more than a half in 2019 to 25.46% from 1980 where it recorded 66.57%.

The agricultural and industrial water withdrawal as percent of total water withdrawal recorded the same evolution only in the first half of the period, i.e., between 1991 and 2000, given that data available for industrial water withdrawal starts with 1990 in contrast to agricultural and municipal water withdrawal, which registered data from 1988. As far back as 2003, the industrial and municipal water withdrawal as percent of total water withdrawal registered the same flow concerning the years in which the level has risen (2004–2007, 2009, 2013, and 2017) or has decreased (2003, 2008, 2010, and 2015–2016) (Fig. 9).

The highest increases for the agriculture water withdrawal were in 2003 (+41.52%), 2008 (+40.24%), 1990 (+32.23%), 2019 (+10.28%), and 2015 (+8.93%), for the industrial water withdrawal in 2002 (+9.06%), 2001 (+8.61%), 2014 (+3.39%), 2004 (+2.78%), and 2007 (+2.67%), and for the municipal water withdrawal in 1990 (+78.11%), 1989 (+20.67%), 1991 (+14.09%), 1992 (+12.85%), and 1993 (+11.86%) as opposed to previous years. The highest diminishes for the agriculture water withdrawal were in 2002 (−23.97%), 2001 (−23.23%), 2007 (−17%), 2004 (−14.62%), and 2014 (−10.42%), for the industrial water withdrawal in 2008 (−5.82%), 2003 (−5.28%), 2012 (−3.19%), 2019 (−2.03%), and 2016 (−1.38%), and for the municipal water withdrawal in 2002 (−13.17%), 2011 (−8.08%), 2003 (−5.28%), 2014 (−4.22%), and 2001 (−4.01%) against previous years (Fig. 9).

The predicted values of the agricultural water withdrawal in the total water withdrawal for 2020–2050 track the general decreasing trend until 2019, namely, 12.53% in 2030, 10.76% in 2040, and 9% in 2050 (Fig. 9a). However, the level of the industrial and municipal water withdrawal in the total water withdrawal is forecasted to rise, for instance 72.66% in 2030, 75.59% in 2040, and 78.51% in 2050 for the industrial water withdrawal (Fig. 9b), and 19.18% in 2030, 22.08% in 2040, and 24.97% in 2050 as regards the municipal water withdrawal (Fig. 9c).

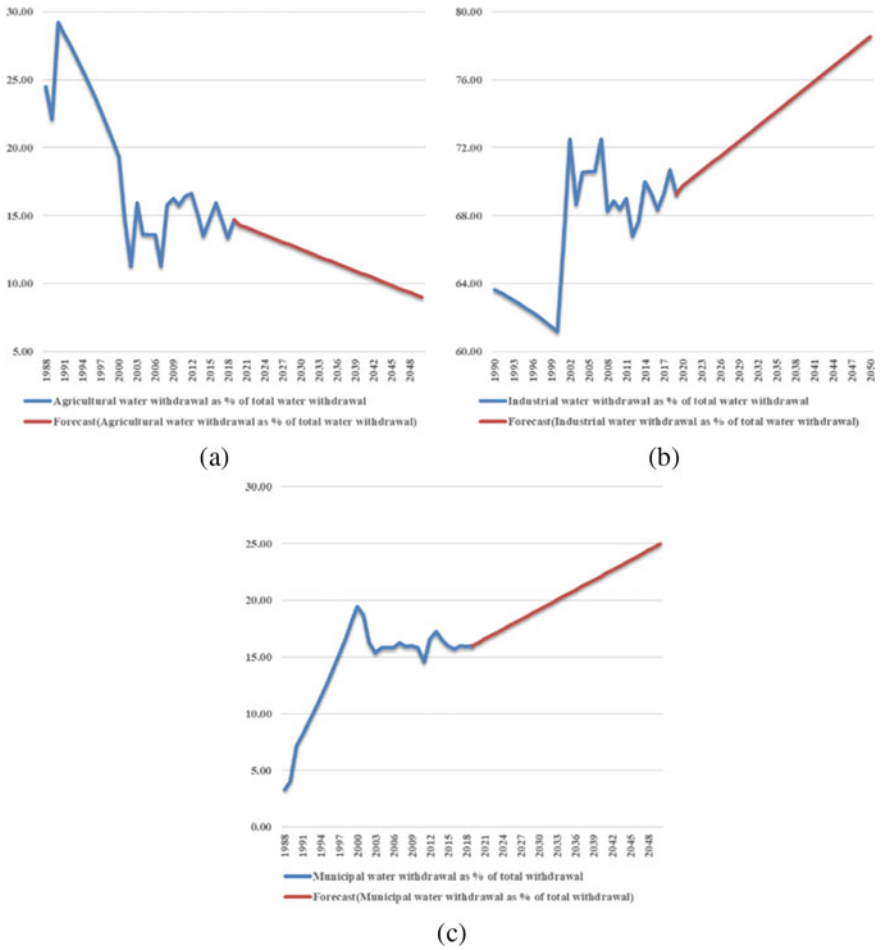

Fig. 9 Evolution and forecasting of Bulgaria's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1988 and 2050 (%). *Source* Made by author based on FAO (2022)

2.5 Cyprus

The total renewable water resources per capita registered a continuous fall between 1961 and 2019, except the 2015 year when it has risen with 30.18% against 2014. The highest diminishes were in 1996 (−26.38%), 1993 (−2.21%), 1994 (−2.19%), 1992 (−2.18%), and 1991 (−2.11%) as opposed to previous years. The predicted values of the total renewable water resources per capita are lower than the level from 2019 (650.77 m^3/inhabit/year), for instance 465.9 m^3/inhabit/year (2030), 332.33 m^3/inhabit/year (2040), and 198.77 m^3/inhabit/year (2050) (Fig. 10a).

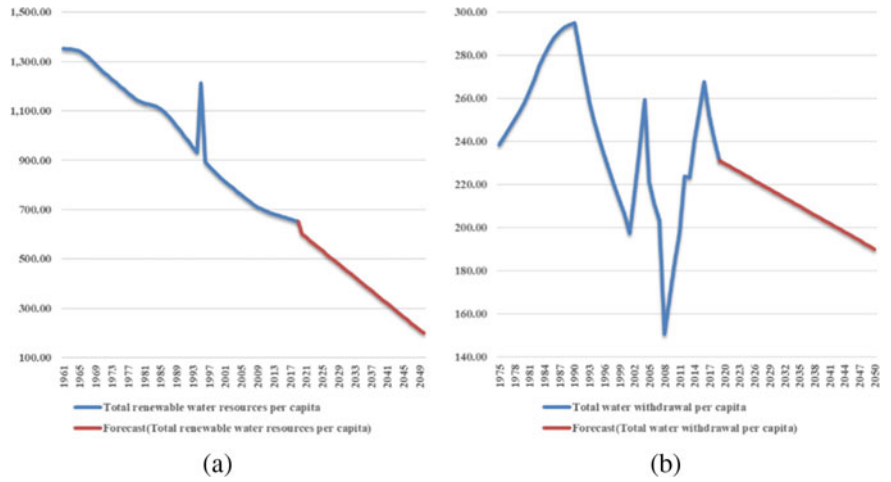

Fig. 10 Evolution and forecasting of Cyprus's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1975 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

As for the total water withdrawal per capita between 1975 and 2019, the increasing periods (1975–1990, 2002–2004, 2009–2012, and 2014–2016) alternates with the decline periods (1991–2001, 2005–2008, 2013, and 2017–2019). The highest expands were in 2012 (+13.23%), 2009 (+11.08%), 2002 (+9.76%), 2004 (+9.51%), and 2003 (+9.41%). In opposed, the highest declines were in 2008 (−26.08%), 2005 (−17.76%), 2017 (−5.88%), 2018 (−4.48%), and 2006 (−4.44%). The predicted level for the total water withdrawal per capita follows a drop trend. Since the level from 2019 was 231.11 m^3/inhabit/year, it is expected to reach 216.54 m^3/inhabit/year in 2030, 203.29 m^3/inhabit/year in 2040, and 190.05 m^3/inhabit/year in 2050 (Fig. 10b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 1975 and 2019, recorded significant variations of growth periods (1975–1990, 1996, 2002–2004, and 2009–2016) and diminish periods (1991–1995, 1997–2001, 2005–2008, and 2017–2019). The lowest value of 19.87% was reported in 1976 and the highest value of 40.13% was recorded in 2016.

The agricultural and municipal water withdrawal as percent of total water withdrawal recorded opposed evolution between 1975 and 2019, that is when the level of agricultural water withdrawal decreased (1976–1990, 2001, 2005–2007, 2010, 2012–2014, and 2017–2019) the level of the municipal water withdrawal increased and vice versa. In the case of the industrial water withdrawal as percent of total water withdrawal, data is available starting with 1986 and its evolution is similar with the agricultural and municipal water withdrawal only for few periods of time (1997–1990, 2005–2007, and 2017–2019 with municipal, 1991–1993 and 2012–2014 with agricultural) (Fig. 11).

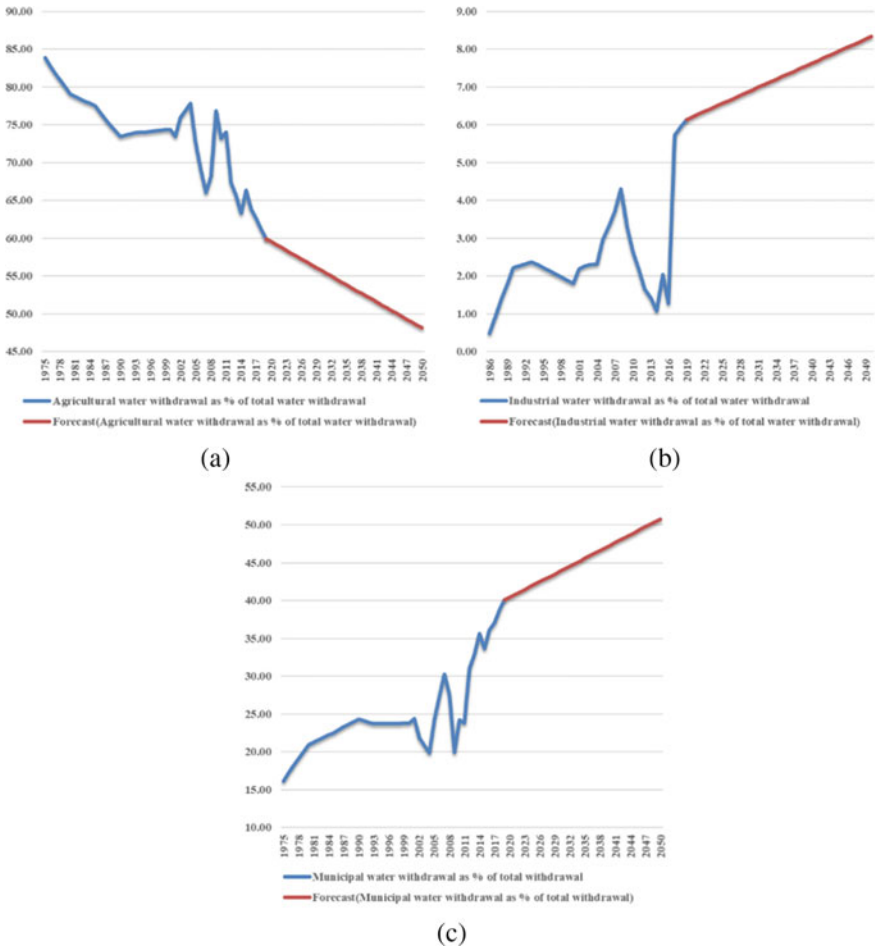

Fig. 11 Evolution and forecasting of Cyprus's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1975 and 2050 (%). *Source* Made by author based on FAO (2022)

The highest boosts for the agriculture water withdrawal were in 2009 (+12.64%), 2015 (+4.77%), 2002 (+3.42%), 2008 (+3.27%), and 2004 (+1.27%), for the industrial water withdrawal in 2017 (+347.9%), 1987 (+95.06%), 2015 (+89.12%), 1988 (+46.38%), and 1989 (+30.19%), and for the municipal water withdrawal in 2012 (+30.37%), 2005 (+21.98%), 2010 (+21.36%), 2006 (+12.66%), and 2007 (+10.86%) in contrast to previous years. The highest decreases for the agriculture water withdrawal were in 2012 (−9.08%), 2005 (−6.44%), 2007 (−4.8%), 2006 and 2010 (−4.73%), and 2016 (−3.66%), for the industrial water withdrawal in

2016 (−37.38%), 2009 (−24%), 2014 (−23.47%), 2012 (−23.42%), and 2010 (−19.08%), and for the municipal water withdrawal in 2009 (−27.56%), 2002 (−10.62%), 2008 (−9.14%), 2015 (−5.44%), and 2004 (−4.72%) as compared to previous years (Fig. 11).

The forecasted values of the agricultural water withdrawal in the total water withdrawal for 2020–2050 trail the overall decline trend until 2019, i.e., 55.74% in 2030, 51.92% in 2040, and 48.11% in 2050 (Fig. 11a). Conversely, the values of industrial and municipal water withdrawal in the total water withdrawal are forecasted to expand, e.g., 6.92% in 2030, 7.63% in 2040, and 8.33% in 2050 for the industrial water withdrawal (Fig. 11b), and 43.87% in 2030, 47.33% in 2040, and 50.78% in 2050 concerning the municipal water withdrawal (Fig. 11c).

2.6 Czechia

In the case of Czechia, data is available beginning with 1993, when the Czechoslovakia has split into Czech Republic (Czechia) and Slovakia (European Union 2022b). The total renewable water resources per capita recorded a lower decrease in 1994, followed by an increase period (1995–2003) and a reduction period (2004–2019). The highest boosts were of + 0.18% (2001 and 2002), +0.17% (2000), + 0.16% (1999), + 0.15% (1998), and +0.12% (1997). The highest drops were in 2008 (−0.65%), 2009 (−0.6%), 2007 (−0.57%), 2010 (−0.46%), and 2006 (−0.39%) against previous years. The forecast values are tracking the decrease trend until 2019 (1,230.21 m^3/inhabit/year), namely 1,204.75 m^3/inhabit/year (2030), 1,181.61 m^3/inhabit/year (2040), and 1,158.46 m^3/inhabit/year (2050) (Fig. 12a).

Concerning the total water withdrawal per capita between 1993 and 2019, its level recorded a continuous shrink with only 3 peaks in 2003 (+13.38%), 2012 (+4.04), and 2016 (+2.33%). The highest diminishes were in 2002 (−15.52%), 2013 (−10.42%), 2019 (−5.49%), 1997 (−4.67%), and 1996 (−4.49%) as opposed to previous years. The predicted values for 2020–2050 period are lower than the level from 2019 (140.89 m^3/inhabit/year), i.e., 117.54 m^3/inhabit/year in 2030, 93.84 m^3/inhabit/year in 2040, and 70.15 m^3/inhabit/year in 2050 (Fig. 12b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 1993 and 2019, shows a decrease trend except 2003, 2012 and 2016 when the level increased as compared to previous years. The highest weight was registered in 1993 and the lowest value in 2019 that is 22.79 and 11.45%, respectively.

The agricultural and municipal water withdrawal as percent of total water withdrawal recorded similar evolution only for the first half of the 1993–2019 period (until 2003). Starting with 2004, the agricultural and industrial water withdrawal as percent of total water withdrawal registered an equivalent evolution until 2019, excluding 2007, 2009, 2012, 2014–2015, and 2018 (Fig. 13).

The highest rises for the agriculture water withdrawal were in 2002 (+84.79%), 2009 (+24.24%), 1994 (+23.24%), 1995 (+20.61%), and 2015 (+15.22%), for the

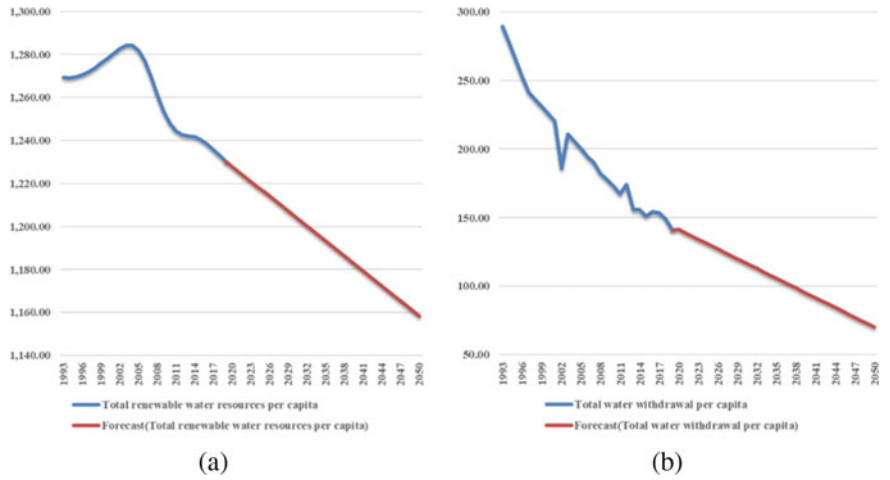

Fig. 12 Evolution and forecasting of Czechia's (**a**) total renewable water resources per capita and (**b**) total water withdrawal per capita between 1993 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

industrial water withdrawal in 2002 (+16.01%), 2013 (+8.39%), 2016 (+2.32%), 2008 (+1.29%), and 1997 (+1.05%), and for the municipal water withdrawal in 2002 (+15.1%), 2018 (+8.73%), 2013 (+8.3%), 2019 (+4.12%), and 1995 (+2.66%) against previous years. The highest cuts for the agriculture water withdrawal were in 1997 (−26.3%), 1996 (−19.29%), 2001 (−15.12%), 2016 (−14.5%), and 2000 (−9.03%), for the industrial water withdrawal in 2003 (−13.65%), 2012 (−6.69%), 2018 (−5.67%), 2015 (−3.4%), and 2019 (−2.96%), and for the municipal water withdrawal in 2003 (−14.36%), 2012 (−4.16%), 2016 (−3.6%), 2014 (−2.63%), and 2007 (−1.88%) as opposed to previous years (Fig. 13).

The estimated level of the agricultural water withdrawal in the total water withdrawal for 2020–2050 follows the increase trend with values of 3.99% in 2030, 4.99% in 2040, and 5.99% in 2050 (Fig. 13a). Oppositely, the level of the industrial water withdrawal in the total water withdrawal is predicted to fall, namely, 57.15% in 2030, 55.74% in 2040, and 54.34% in 2050 (Fig. 13b). In the case of the industrial water withdrawal, its level is predicted to grow between 2020 and 2030 (up to 57.15%) and to decrease in 2040 (55.74%) and 2050 (54.34%) (Fig. 13c).

2.7 Denmark

The total renewable water resources per capita recorded a decrease trend between 1961 and 2019, except the 1983–1986 period where it has risen (+0.07% in 1984 and 1985, and 0.04% in 1983 and 1986). The highest falls were in 1964 and 1965 (−0.79%), 1966 (−0.77%), 1963 (−0.76%), 1967 (−0.75%), and 1968 (−0.71%)

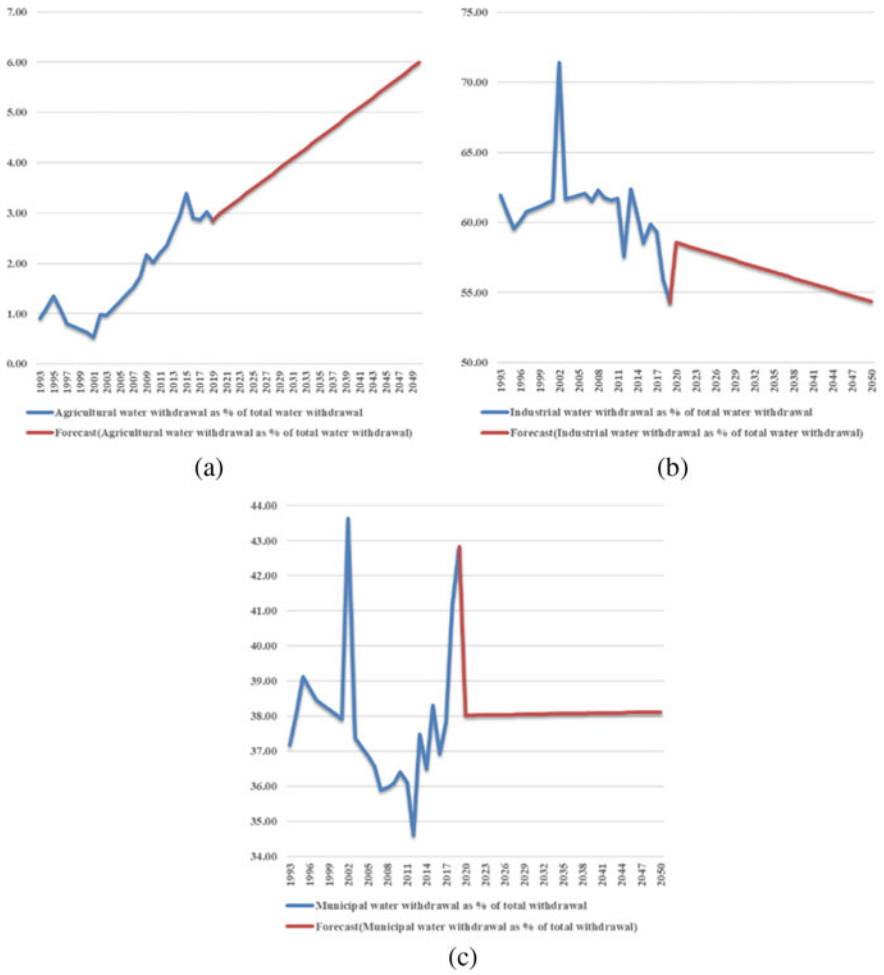

Fig. 13 Evolution and forecasting of Czechia's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1993 and 2050 (%). *Source* Made by author based on FAO (2022)

as opposed to previous years. The estimate values for 2020–2050 describe a decease trend with an average decline rate of 0.36% per year. Thus, starting with the level recorded in 2019 of 1,039.52 m^3/inhabit/year, the expected levels are 1,000.19 m^3/inhabit/year (2030), 964.43 m^3/inhabit/year (2040), and 928.68 m^3/inhabit/year (2050) (Fig. 14a).

In respect to the total water withdrawal per capita between 1970 and 2019, its evolution is characterized by the fluctuation of growth periods (1971–975, 1981–1985, 1989–1990, 1996, 2004, 2006, 2008, 2010–2011, 2013, and 2016–2018) with decline periods (1976–1980, 1986–1988, 1991–1995, 1997–2003, 2005, 2007, 2009,

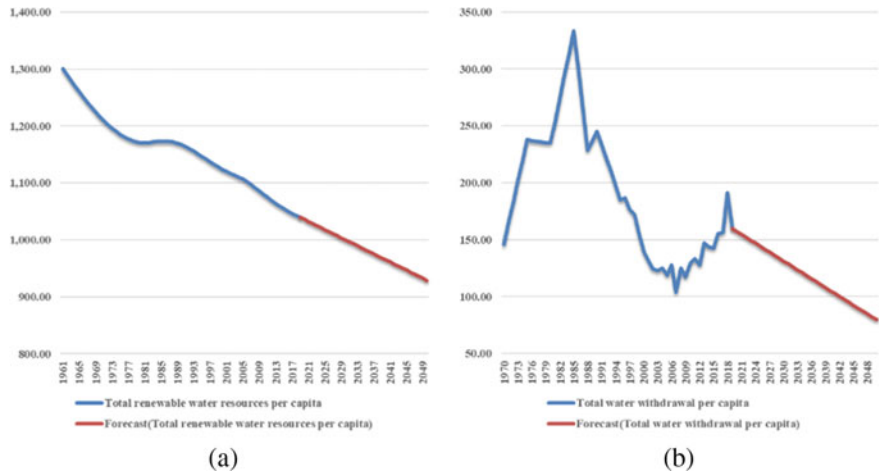

Fig. 14 Evolution and forecasting of Denmark's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1970 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

2012, 2014–2015, and 2019). Increases such as +22.31% (2018), +20.21% (2008), +15.38% (2013), +12.77% (1971), and +11.23% (1972) were the highest and diminished equal to −18.42% (2007), −16.4% (2019), −13.31% (1988), −11.71% (1987), and −10.48% (1986) were the highest. The prognosis for 2020–2050 period highlights a fall trend with values lower than the level from 2019 (159.8 m^3/inhabit/year), for example, 131.33 m^3/inhabit/year in 2030, 105.45 m^3/inhabit/year in 2040, and 79.58 m^3/inhabit/year in 2050 (Fig. 14b).

Between 1970 and 2019, the weight of the total water withdrawal per capita in the total renewable water resources per capita recorded a zigzag evolution due to the trend of the total water withdrawal per capita, such as 12% (1970), 28.42% (1985), 9.51% (2007—the lowest value), and 15.37% (2019).

There are partial similarities in different combinations of the evolution among the agricultural, industrial and municipal water withdrawal as percent of total water withdrawal. Thus, between 1976 and 1980, all three indicators have maintained their level from 1975. Furthermore, between 1981 and 2002, the agricultural and industrial water withdrawal as percent of total water withdrawal recorded the same evolution, and the municipal water withdrawal as percent of total water withdrawal registered a converse movement. Beginning with 2003 and until 2015, the industrial and municipal water withdrawal as percent of total water withdrawal registered approximatively the same trend (Fig. 15).

The highest boosts for the agriculture water withdrawal were in 2008 (+72.37%), 2013 (+53.98%), 2006 (+24.46%), 1997 (+16.97%), and 1971 (+15.54%), for the industrial water withdrawal in 1981 (+109.3%), 2010 (+70.22%), 1982 (+44.79%), 2011 (+41.97%), and 2012 (+37.16%), and for the municipal water withdrawal in 1989 (+26.42%), 2007 (+20.41%), 1990 (+19.39%), 2019 (+14.27%), and 2000

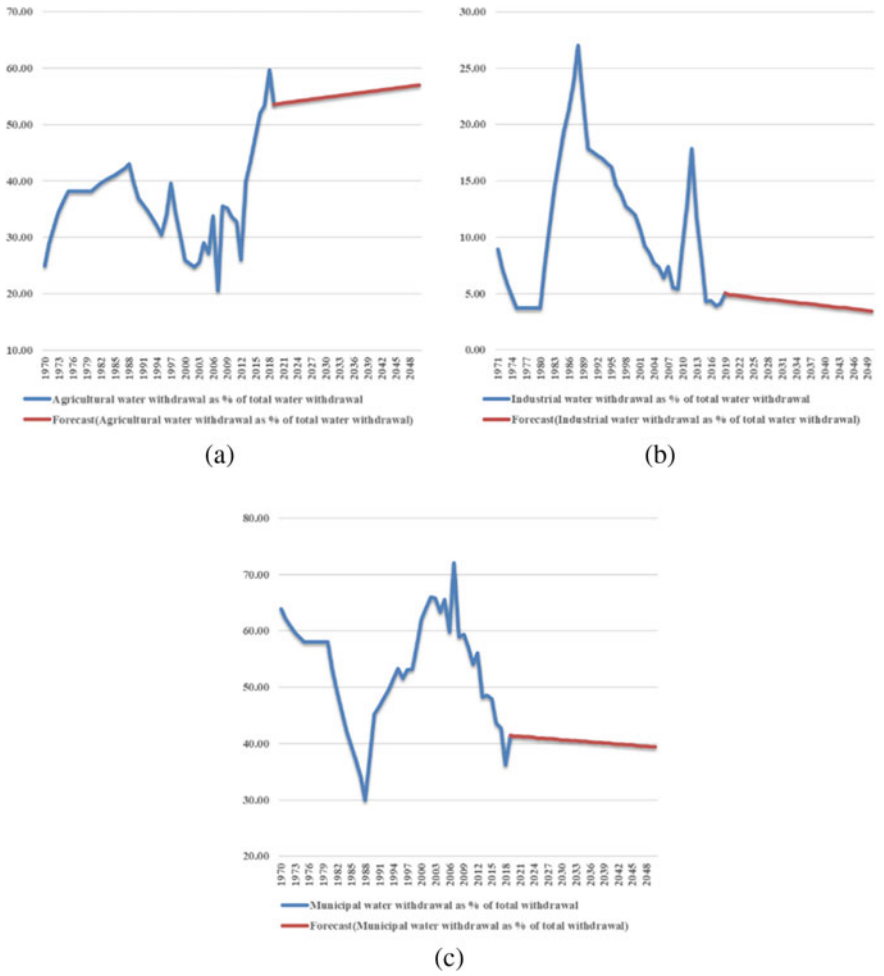

Fig. 15 Evolution and forecasting of Denmark's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1970 and 2050 (%). *Source* Made by author based on FAO (2022)

(+8.61%) in contrast to previous years. The highest shrinks for the agriculture water withdrawal were in 2007 (−39.05%), 2012 (−20.67%), 2000 (−14.75%), 1998 (−13.9%), and 1999 (−10.76%), for the industrial water withdrawal in 2015 (−46.82%), 2013 (−34.66%), 2014 (−30.84%), 2008 (−25.33%), and 1975 (−20.43%), and for the municipal water withdrawal in 2008 (−18.08%), 2018 (−15.27%), 2013 (−14.01%), 1988 (−11.85%), and 2016 (−9.11%) as compared to previous years (Fig. 15).

The foreseen level of the agricultural water withdrawal in the total water withdrawal for 2020–2050 is tracking a slight expand trend with values of 54.77% in

2030, 55.87% in 2040, and 56.97% in 2050 (Fig. 15a). On the contrary, the predicted values of the industrial water withdrawal in the total water withdrawal are on decrease trend, i.e. 4.41% in 2030, 3.93% in 2040, and 3.46% in 2050 (Fig. 15b). The same reduction trend is followed by the values of the municipal water withdrawal that is 40.69% in 2030, 40.04% in 2040, and 39.4% in 2050 (Fig. 15c).

2.8 Finland

The analysis of the total renewable water resources per capita underlines a continuous reduction trend between 1961 and 2019. Therefore, the highest falls were in 1962 (−0.69%), 1963 (−0.62%), 1983 (−0.56%), 1984 and 1993 (−0.53%), and 1973 (−0.52%) against previous years. The forecast for 2020–2050 period underscores the same decrease trend, with an average decline rate of 0.18% per year. Taking into account the level from 2019 was 19,883.75 m^3/inhabit/year, the predicted values are 19,496.72 m^3/inhabit/year (2030), 19,144.89 m^3/inhabit/year (2040), and 18,793.06 m^3/inhabit/year (2050) (Fig. 16a).

Referring to the total water withdrawal per capita between 1970 and 2019, the rise periods (1970–1985, 1991–1995, 2000, 2006, 2008–2013, 2015, and 2018–2019) alternate with decline periods (1986–1990, 1996–1999, 2001–2005, 2007, 2014, and 2016–2017). The highest booms were in 2006 (+190.22%), 2018 (+21.49%), 2019 (+3.39%), 1991 (+1.57%), and 1992 (+1.47%), and the highest falls were in 2007 (−65.43%), 1990 (−12.68%), 1989 (−11.28%), 1988 (−10.17%), and 1987 (−9.3%). All the estimate values for 2020–2050 period are lower than the level

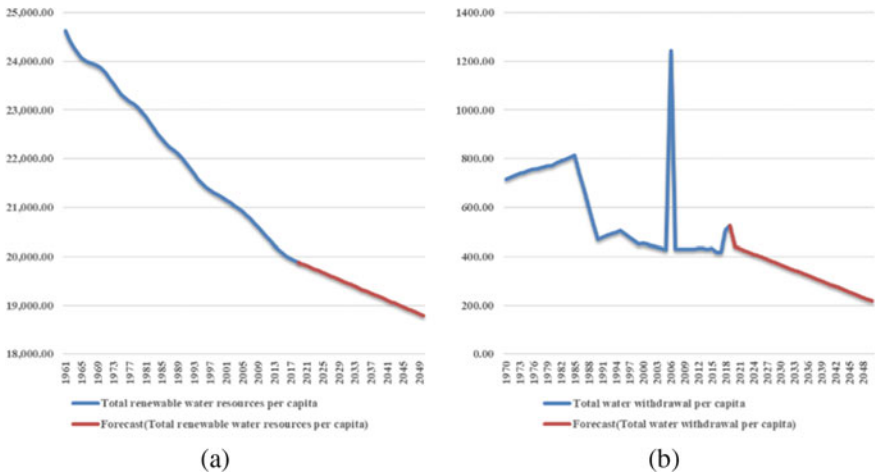

Fig. 16 Evolution and forecasting of Finland's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1970 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

from 2019 (524.21 m^3/inhabit/year), namely, 366.34 m^3/inhabit/year in 2030, 292.29 m^3/inhabit/year in 2040, and 218.23 m^3/inhabit/year in 2050 (Fig. 16b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 1970 and 2019, followed the evolution of the total water withdrawal per capita with values bounded by 2.05 and 5.97%.

The same evolution is highlighted for the agricultural, industrial and municipal water withdrawal as percent of total water withdrawal between 1996 and 1999, the agricultural and industrial water withdrawal between 1991 and 1999, the agricultural and municipal water withdrawal between 1996 and 2007, and the industrial and municipal water withdrawal between 2008 and 2015 (Fig. 17).

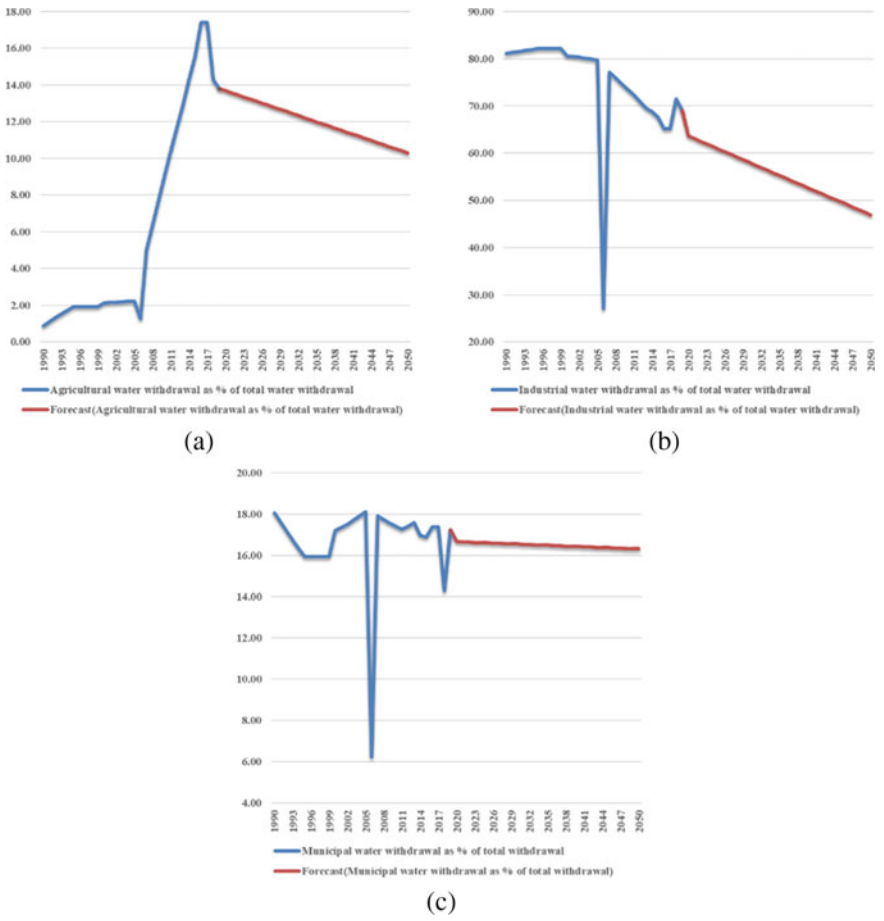

Fig. 17 Evolution and forecasting of Finland's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1990 and 2050 (%). *Source* Made by author based on FAO (2022)

The highest increases for the agriculture water withdrawal were in 2007 (+300.22%), 2008 (+27.42%), 1991 (+27.41%), 2009 (+21.32%), and 1992 (+20.67%), for the industrial water withdrawal in 2007 (+184.99%), 2018 (+9.52%), 1991 (+0.28%), 1992 (+0.27%), and 1993 (+0.26%), and for the municipal water withdrawal in 2007 (+186.84%), 2019 (+20.69%), 2000 (+8.06%), 2016 (+2.96%), and 2004 and 2005 (+1.14%) as compared to previous years. The agriculture water withdrawal recorded only three falls, i.e., 2006 (−43.81%), 2018 (−17.86%), and 2019 (−3.45%). The highest diminishes were for the industrial water withdrawal in 2006 (−66.04%), 2016 (−3.47%), 2019 (−3.45%), 2013 (−2.01%), and 2012 (−2%) and for the municipal water withdrawal in 2006 (−65.55%), 2018 (−17.86%), 2014 (−3.5%), 1991 (−2.55%), and 1992 (−2.52%) as opposed to previous years (Fig. 17).

The expected values of the agricultural water withdrawal in the total water withdrawal for 2020–2050 track the decrease trend started in 2018 with levels of 12.55% in 2030, 11.42% in 2040, and 10.29% in 2050 (Fig. 17a). The same drop trend is projected for the industrial water withdrawal in the total water withdrawal, such as 58.05% in 2030, 52.49% in 2040, and 46.94% in 2050 (Fig. 17b). A smoother decrease trend is anticipated for the municipal water withdrawal, for example 16.54% in 2030, 16.43% in 2040, and 16.31% in 2050 (Fig. 17c).

2.9 France

The total renewable water resources per capita recorded a continuous, steady reduction trend, between 1961 and 2019, without any increase. The highest drops were in 1963 (−1.37%), 1962 (−1.36%), 1964 (−1.29%), 1965 (−1.15%), and 1966 (−0.99%) versus previous years. The predicted values for 2020–2050 also decrease with an average decline rate of 0.22% per year, starting with 3,239.69 m^3/inhabit/year down to 3,164.43 m^3/inhabit/year (2030), 3,096.06 m^3/inhabit/year (2040), and 3,027.7 m^3/inhabit/year (2050) (Fig. 18a).

By exploring the evolution of the total water withdrawal per capita between 1980 and 2019, its overall decreasing trend can be underscored, even if the expand periods (1981–1992, 1998–2000, 2011, 2014–2015, and 2017) are interchanging with fall periods (1993–1997, 2011–2010, 2012–2013, 2016, and 2018–2019). The highest growths were in 2011 (+4.91%), 2015 (+2.59%), 1998 (+2.22%), 1991 (+2.1%), and 1999 (+2.09%), and the highest drops were in 2008 (−7.94%), 2012 (−7.41%), 2016 (−6.28%), 1997 (−5.87%), and 1996 (−5.58%). The forecast level for 2020–2050 period is lower than the level from 2019 (412.24 m^3/inhabit/year). It is achievable only until 2040 (137.86 m^3/inhabit/year) or at most until 2045 (126.75 m^3/inhabit/year), because after this year the level decline under 100 m^3/inhabit/year and starting with 2049, the level is negative which is less probable to happen (Fig. 18b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 1980 and 2019, maintained the decrease trend of the total water withdrawal per capita with few rise periods, with variations between 14.68% in 1980 and 12.72% in 2019.

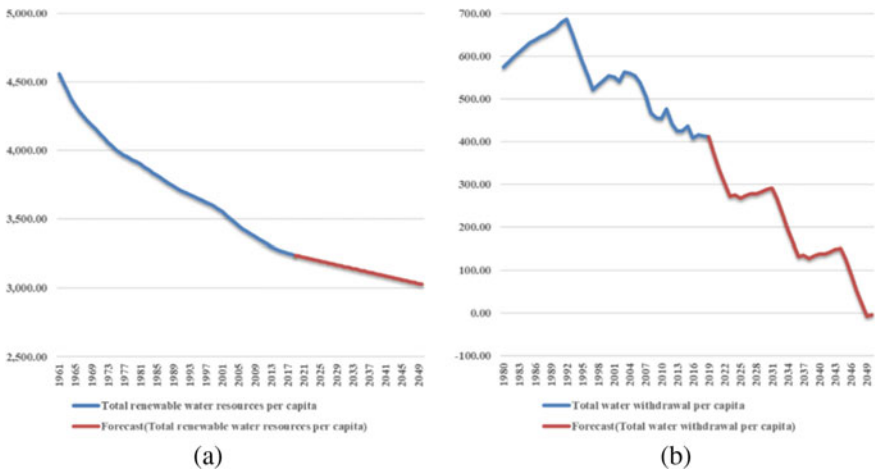

Fig. 18 Evolution and forecasting of France's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1980 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

The agricultural, industrial and municipal water withdrawal as percent of total water withdrawal have recorded the same evolution in not many long periods of time, except 1993–1997 for the agricultural and industrial and 1998–2002 for the industrial and municipal. The highest increases for the agriculture water withdrawal were in 2015 (+47.56%), 2009 (+23.96%), 2003 (+22.54%), 1998 (+12.22%), and 1999 (+10.35%), for the industrial water withdrawal in 2014 (+4.75%), 2008 (+3.12%), 2011 (+2.99%), 2007 (+1.9%), and 2002 (+1.43%), and for the municipal water withdrawal in 2008 (+8.03%), 1997 (+5.52%), 2016 (+5.51%), 2013 (+5.28%), and 2012 (+5.27%) in contrast to previous years. The highest shrinks for the agriculture water withdrawal were 2008 (−28.91%), 2014 (−24.24%), 2007 (−12.91%), 2002 (−8.99%), and 2017 (−7.24%), for the industrial water withdrawal in 2015 (−3.95%), 2003 (−3.04%), 2009 (−2.74%), 2016 (−1.95%), and 2012 (−1.77%) and for the municipal water withdrawal in 2011 (−7.8%), 2003 (−4.96%), 2015 (−4.14%), 2014 (−4.11%), and 1998 (−2.64%) against previous years (Fig. 19).

The foreseen of the agricultural water withdrawal in the total water withdrawal for 2020–2050 move on a decline trend, with values lower than those of 2019 (11.13%), such as 10.11% in 2030, 9.19% in 2040, and 8.28% in 2050 (Fig. 19a). The values of the industrial water withdrawal in the total water withdrawal are planned to fall as well, this is 68.48% in 2030, 67.96% in 2040, and 67.43% in 2050 (Fig. 19b). Conversely, an increase trend is expected for the municipal water withdrawal in the total water withdrawal, in particular, 21.18% in 2030, 21.99% in 2040, and 24.29% in 2050 (Fig. 19c).

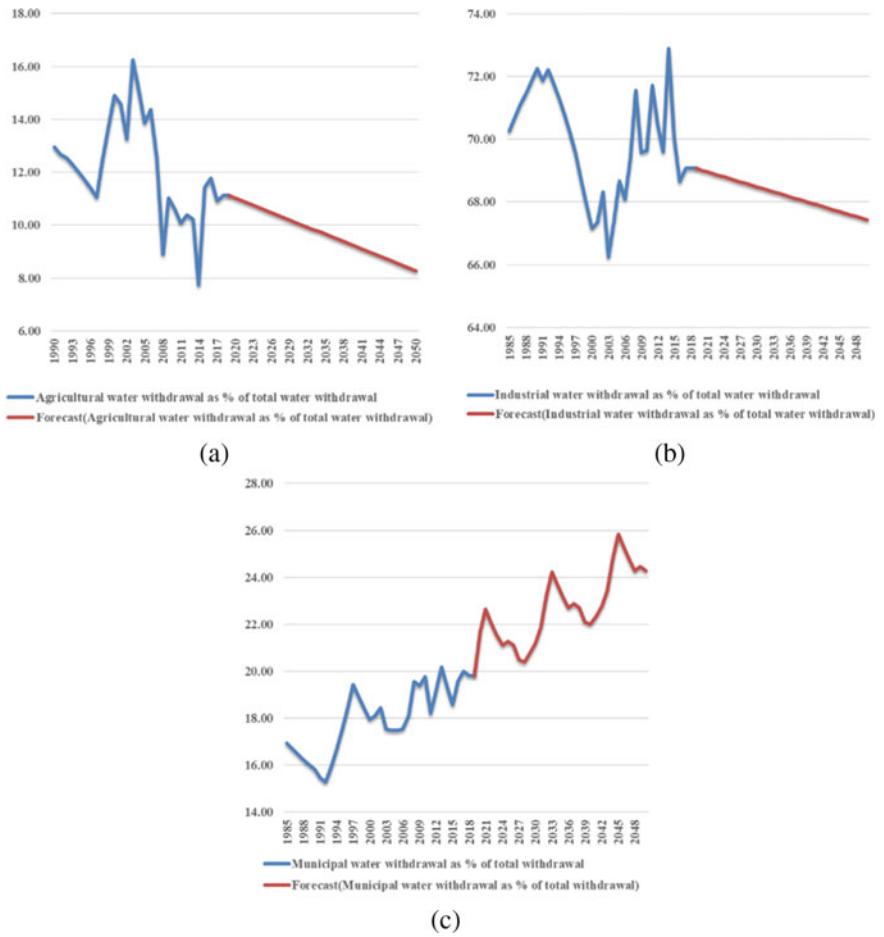

Fig. 19 Evolution and forecasting of France's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1985 and 2050 (%). *Source* Made by author based on FAO (2022)

2.10 Germany

The total renewable water resources per capita recorded a fluctuate evolution of a decline trend between 1961 and 2019. There are four decline periods (1962–1973, 1985–1997, 2000–2004, and 2011–2019) and three rise periods (1974–1984, 1989, and 2005–2010). The highest falls were in 1963 and 1964 (−0.79%), 1965 (−0.76%), 1962 (−0.75%), 1966 (−0.73%), and 1967 (−0.7%), and the highest growths were in 2008 (+0.26%), 2007 (+0.24%), 1982 (+0.23%), 1981 (+0.22%), and 1980, 1983 and 2009 (+0.2%) as opposed to previous years. The probable level for 2020–2050 declines as well with an average decline rate of 0.26% per

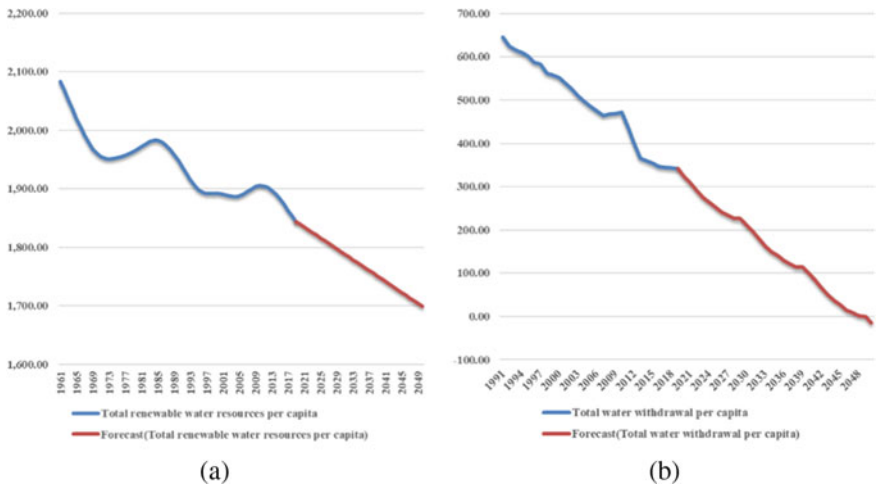

Fig. 20 Evolution and forecasting of Germany's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1991 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

year, taking into account that the level from 2019 was 1,843.93 m^3/inhabit/year, i.e. 1,792.68 m^3/inhabit/year (2030), 1,746.08 m^3/inhabit/year (2040), and 1,699.48 m^3/inhabit/year (2050) (Fig. 20a).

The same decline trend is tracked by the evolution of the total water withdrawal per capita between 1991 and 2019, with the difference that there are only two diminish periods (1991–2007 and 2011–2019) and one increase period (+0.58% in 2008, +0.52% in 2009, and +0.4% in 2010 as compared to previous years). The highest diminishes were in 2013 (−8.86%), 2012 (−8.08%), 2011 (−7.4%), 1998 (−3.33%), and 1992 (−3.11%). The expected values for 2020–2050 are lower than the level from 2019 (341.03 m^3/inhabit/year) and are possible for 2030 (211.13 m^3/inhabit/year) and for 2040 (98.42 m^3/inhabit/year). Thus, beyond 2040, the values are below 100 m^3/inhabit/year and starting with 2050, the values are negative which is not reasonable (Fig. 20b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 1991 and 2019, registered the same decline trend, the highest value was recorded in 191 (33.28%) and the lowest value was the same in 2017–2019 period (18.49%).

There are matches among the evolution of agricultural, industrial and municipal water withdrawal as percent of total water withdrawal, for example in 1992–1998 and 2008–2010 in the case of the agricultural and industrial, in 1999–2007 and 2011–2019 for the agricultural and municipal, and in 2017–2019 for the agricultural, industrial and municipal because their level remained unchanged. The highest expands for the agriculture water withdrawal were in 2013 (+15.57%), 2012 (+15.07%), 2011 (+14.74%), 2008 (+7.49%), and 2009 (+6.88%), for the industrial water withdrawal in 2008–2010 (+0.34%), 2003–2004 (+0.06%), and 2002 (+0.05%), and for the

municipal water withdrawal in 2013 (+8.81%), 2012 (+8%), 2011 (+7.32%), 1992 (+3.81%), and 2007 (+3.69%) against previous years. The highest cuts for the agriculture water withdrawal were in 1998 (−30.62%), 1997 (−24.16%), 1996 (−18.06%), 1995 (−13.63%), and 1994 (−11.89%), for the industrial water withdrawal in 2013 (−4.56%), 2012 (−3.69%), 2011 (−3.05%), 2007 (−1.45%), and 2006 (−1.36%) and for the municipal water withdrawal in 2010 (−1.03%), 2008 and 2009 (−1.02%), 2004 (−0.13%), and 2002 and 2003 (−0.12%) versus previous years (Fig. 21).

The projected value of the agricultural water withdrawal in the total water withdrawal for 2020–2050 follows a decrease trend, with values lower than 1,4% (2019), for instance 1.23% in 2030, 1.07% in 2040, and 0.92% in 2050 (Fig. 21a). The level

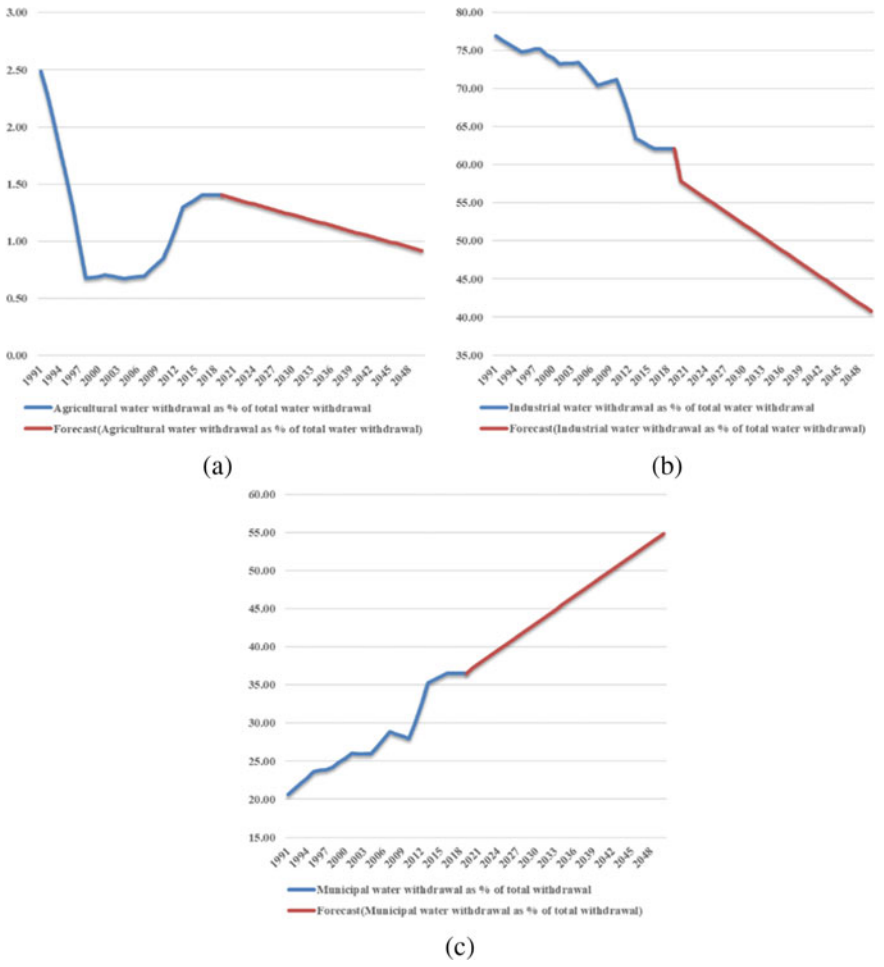

Fig. 21 Evolution and forecasting of Germany's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1991and 2050 (%). *Source* Made by author based on FAO (2022)

of the industrial water withdrawal in the total water withdrawal is also on a decline trend, e.g. 52.14% in 2030, 46.46% in 2040, and 40.78% in 2050 (Fig. 21b). By opposite, the level of the municipal water withdrawal in the total water withdrawal trails an increase tendency, like 43.13% in 2030, 48.97% in 2040, and 54.82% in 2050 (Fig. 21c).

2.11 Ireland

The analysis of the evolution of the total renewable water resources per capita, between 1961 and 2019, emphasizes a reduction trend. There are two decline periods (1962–1986 and 1990–2017) and only one growth period (+0.02% in 1987, +0.1% in 1988, and 0.08% in 1989 versus previous years). The highest drops were in 2007 (−2.17%), 2006 (−2.11%), 2008 (−2.07%), 2005 (−2.01%), and 2004 (−1.92%) as compared to previous years. The forecast value for 2020–2050 records the same decline trend from 10,650.29 m^3/inhabit/year in 2019 to 9,104.5 m^3/inhabit/year in 2030, 7,699.13 m^3/inhabit/year in 2040, and 6,293.77 m^3/inhabit/year in 2050 (Fig. 22a).

The evolution of the total water withdrawal per capita between 1980 and 2019 has shown a fluctuation of fall periods (1981–1983, 1995–2002, 2005, 2007, 2009, 2015, and 2018) and rise periods (1984–1994, 2003–2004, 2006, 2008, 2010–2014, 2016–2017, and 2019). The highest diminishes were in 2007 (−24.72%), 2018 (−23.15%), 2005 (−23.11%), 2009 (−16.02%), and 2002 (−4.45%), and the highest boosts were in 2019 (+40.84%), 2010 (+23.14%), 2008 (+18.81%), 2006 (+16.22%), and

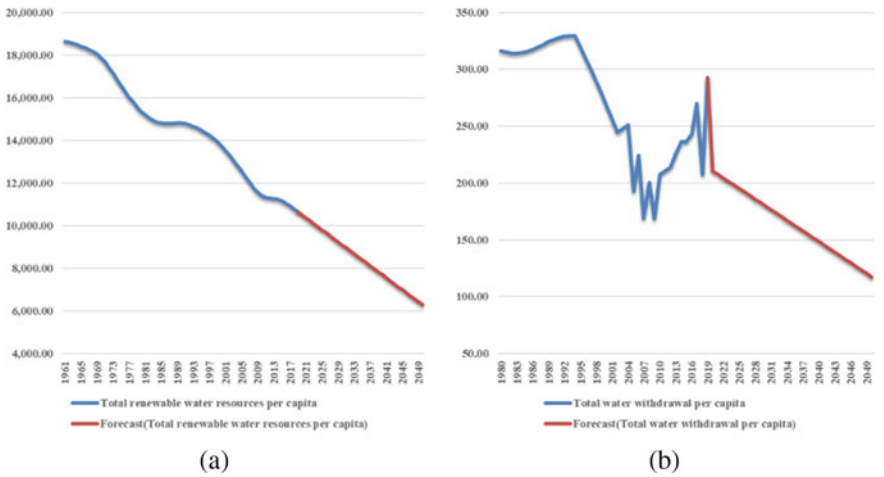

Fig. 22 Evolution and forecasting of Ireland's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1980 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

2017 (+11.21%) as compared to previous years. The anticipated level for 2020–2015 is below the level from 2019 (292.27 m^3/inhabit/year), for instance 179.5 m^3/inhabit/year in 2030, 148.42 m^3/inhabit/year in 2040, and 117.34 m^3/inhabit/year in 2050 (Fig. 22b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 1980 and 2019, recorded variations between 2.71% (the highest level) in 2019 and 1.4% (the lowest level) in 2007.

The evolution of agricultural and municipal water withdrawal as percent of total water withdrawal recorded the same evolution in 1981–1994 and 2011–2016. Conversely, the industrial water withdrawal as percent of total water withdrawal registered an opposite trend against the municipal water withdrawal as percent of total water withdrawal in 1981–2004, 2006, 2008–2009, and 2011–2019 (Fig. 23).

The highest increases for the agriculture water withdrawal were in 2007 (+24.89%), 2015 (+22.85%), 2018 (+19.62%), 2009 (+12.05%), and 1981 (+1.97%), for the industrial water withdrawal in 2009 (+70.26%), 2008 (+51.34%), 2018 (+39.83%), 2011 (+21.19%), and 2012 (+16.76%), and for the municipal water withdrawal in 2019 (+42.18%), 2006 (+13.58%), 2003 (+8.98%), 2004 (+7.73%), and 2002 (+5.39%) as compared to previous years. The highest falls for the agriculture water withdrawal were in 2019 (−29.92%), 2010 (−23.39%), 2008 (−20.91%), 2006 (−18.93%), and 2017 (−16.83%), for the industrial water withdrawal in 2006 (−40.6%), 2019 (−29.92%), 2007 (−24.36%), 2004 (−21.07%), and 2003 (−18.35%) and for the municipal water withdrawal in 2019 (−27.67%), 2009 (−11.67%), 2015 (−5.42%), and 2012 (−4.72%) as opposed to previous years (Fig. 23).

The estimated level of the agricultural water withdrawal in the total water withdrawal for 2020–2050 tracks a decline trend, starting with 4.56% in 2019 and reaching 2.71% in 2030 and 1.03% in 2040. The predictions for 2041–2050 cannot be used because beyond 2041 the level in lower than 1% and further than 2047 the level is negative (Fig. 23a). The level of the industrial water withdrawal in the total water withdrawal is on a fall trend as well, for instance 29.19% in 2030, 22.61% in 2040, and 16.02% in 2050 (Fig. 23b). By contrast, the level of the municipal water withdrawal in the total water withdrawal follows a growth trend, e.g. 68.1% in 2030, 76.36% in 2040, and 84.63% in 2050 (Fig. 23c).

2.12 Italy

The evolution of the total renewable water resources per capita, between 1961 and 2019, underlines a decline trend with two long decrease periods (1962–1994 and 2000–2017) and two short periods (1995–1999 and 2018–2019). Firstly, the highest diminishes were in 1963 and 1964 (−0.81%), 1965 (−0.78%), 1962 (−0.77%), 1966 (−0.74%), and 1967 (−0.71%) against previous years. Secondly, the highest boosts were in 1997 and 1998 (+0.28%), 1996 (+0.19%), 1999 (+0.15%), 2019

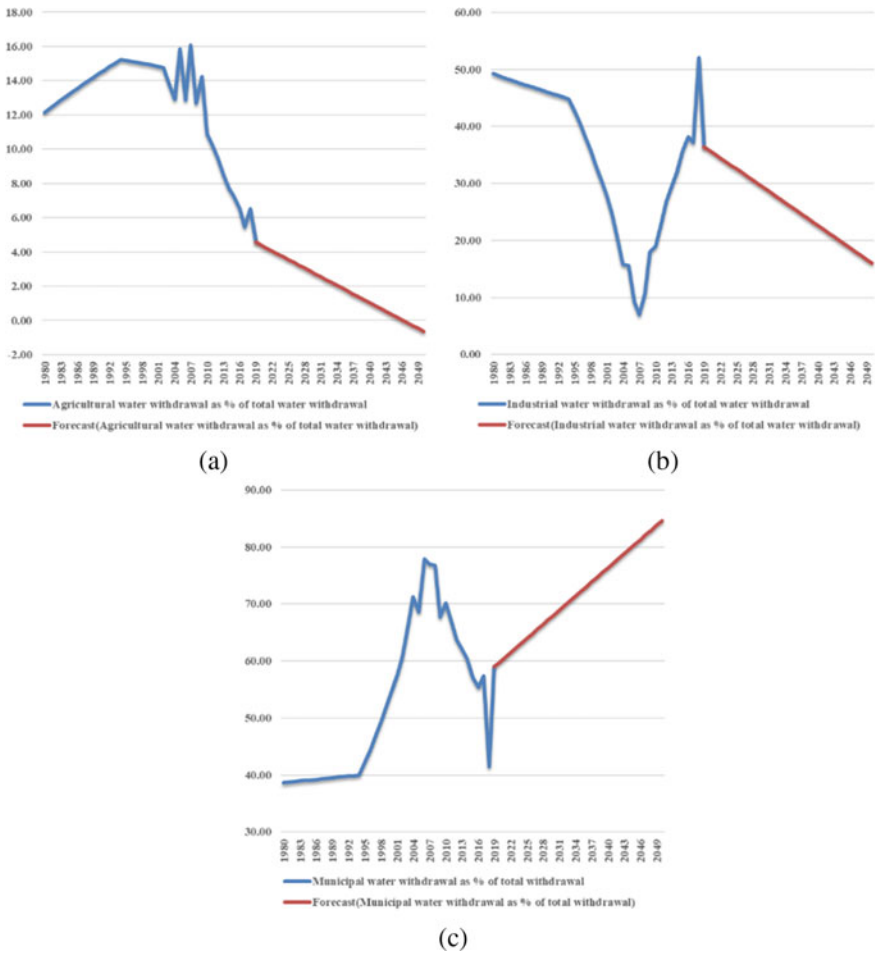

Fig. 23 Evolution and forecasting of Ireland's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1980 and 2050 (%). *Source* Made by author based on FAO (2022)

(+0.13%), and 2018 (+0.08%) versus previous years. The foresee value for 2020–2050 registers also a decrease trend from 3,159.37 m^3/inhabit/year in 2019 to 3.058.91 m^3/inhabit/year in 2030, 2.967.58 m^3/inhabit/year in 2040, and 2.876.25 m^3/inhabit/year in 2050 (Fig. 24a).

As for the evolution of the total water withdrawal per capita between 1970 and 2019, each rise period (1971–1980, 1991–2000, 2008, and 2018–2019) alternated with a reduction period (1981–1990, 2001–2007, and 2009–2017). The highest increases were in 2008 (+59.5%), 1997 (+1.42%), 1998 (+1.41%), 1996 (+1.34%), and 1995 (+1.23%) as opposed to previous years. The highest drops were in 2009 (−37.34%), 2005 (−4.97%), 2007 (−4.95%), 2004 (−4.87%), and 2006 (−4.84%)

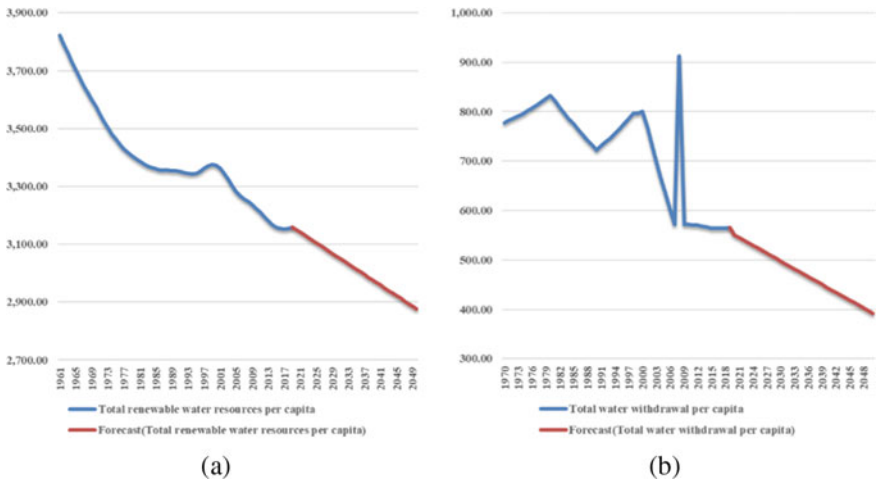

Fig. 24 Evolution and forecasting of Italy's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1970 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

versus previous years. The expected values for 2020–2050 are lower than the 654.62 m^3/inhabit/year (2019), e.g. 467.68 m^3/inhabit/year in 2030, 444.95 m^3/inhabit/year in 2040, and 392.21 m^3/inhabit/year in 2050 (Fig. 24b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 1970 and 2019, registered moderate differences from 21.75% in 1970 to 17.87% in 2019, except 2008–2009 period. The peak of 28.1% was recorded in 2008 and the minimum value of 17.66% was recorded in 2009.

There is a similar evolution among the agricultural, industrial and municipal water withdrawal as percent of total water withdrawal, namely in 1971–1980 and 2009–2013 in the case of the agricultural and municipal, in 1981–1999 and 2008–2009 for the industrial and municipal, and in 2016–2019 for the agricultural, industrial and municipal because their level remained constant. Between 1971 and 2000, and 2010 and 2013 the evolution of industrial water withdrawal was perfectly opposed to agricultural water withdrawal (Fig. 25).

The highest increases for the agriculture water withdrawal were in 2009 (+67.11%), 2010 (+4.45%), 2011 (+4.24%), 2012 (+4.04%), and 2013 (+3.98%), for the industrial water withdrawal in 2009 (+49.53%), 1971 (+5.51%), 1972 (+5.09%), 1973 (+4.72%), and 1974 (+4.4%), and for the municipal water withdrawal in 2009 (+60.64%), 2007 (+5.44%), 2006 (+5.22%), 2005 (+4.3%), and 2004 (+4.1%) in contrast to previous years. The highest reductions for the agriculture water withdrawal were in 2008 (−34.17%), 2007 (−2.83%), 2006 (−2.51%), 2005 (−2.05%), and 1991 (−1.95%), for the industrial water withdrawal in 2008 (−41.03%), 2013 (−8.1%), 2012 (−7.63%), 2011 (−7.13%), and 2010 (−6.7%) and for the municipal water withdrawal in 2008 (−37.14%), 2000 (−0.79%), 1990 (−0.7%), 1989 (−0.67%), and 1988 (−0.65%) as opposed to previous years (Fig. 25).

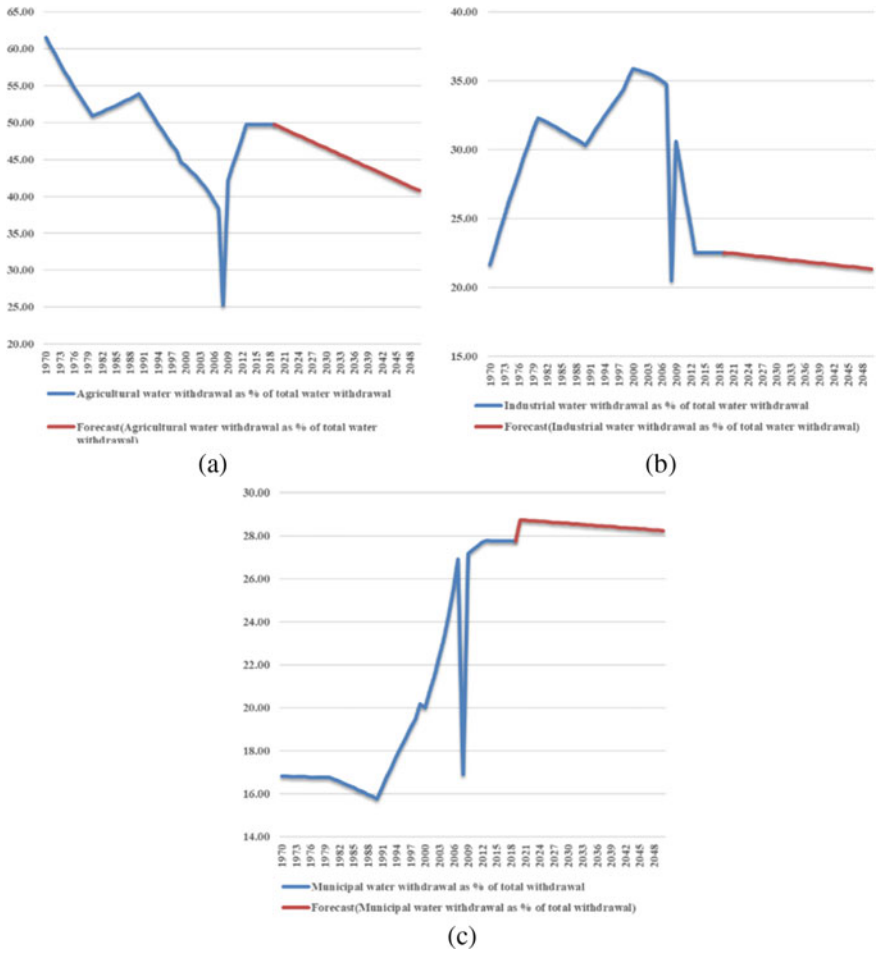

Fig. 25 Evolution and forecasting of Italy's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1970 and 2050 (%). *Source* Made by author based on FAO (2022)

The expected value of the agricultural, industrial and municipal water withdrawal as percent of total water withdrawal for 2020–2050 follows the same decrease trend. Thus, the agricultural water withdrawal in the total water withdrawal recorded a value of 49.73% in 2019 and it is possible to register 46.55% in 2030, 43.66% in 2040, and 40.77% in 2050 (Fig. 25a). The industrial water withdrawal in the total water withdrawal registered a level of 22.52% in 2019 and it is likely to score 22.1% in 2030, 21.71% in 2040, and 21.33% in 2050 (Fig. 25b). The municipal water withdrawal in the total water withdrawal recorded a level of 27.75% in 2019 and it is supposed to register 28.58% in 2030, 27.41% in 2040, and 28.24% in 2050 (Fig. 25c,b).

2.13 Luxembourg

Between 1961 and 2019, the evolution of the total renewable water resources per capita recorded a continuous fall. The highest decreases were in 2009 and 2010 (−2.24%), 2011 (−2.2%), 2012 (−2.18%), 2008 and 2013–2017 (−2.16%), and 2017 (−2.04%) as opposed to previous years. The forecast level for 2020–2050 tracks a fall trend, as well, from 5,684.32 m^3/inhabit/year in 2019 to 4,481 m^3/inhabit/year in 2030, 3,387,316 m^3/inhabit/year in 2040, and 2,293,29 m^3/inhabit/year in 2050 (Fig. 26a).

Conversely, the total water withdrawal per capita scored an evolution in which the increase periods (1971–1975, 1981–1985, 1996–1999, 2014, and 2017–2018) fluctuate with the decline periods (1976–1980, 1986–1995, 2000–2013, 2015–2016, and 2019). The highest boosts were in 1991 (+13.64%), 2018 (+12.14%), 1982 (+12.01%), 1983 (+10.71%), and 1984 (+9.68%), and the highest diminishes were in 2012 (−10.24%), 2019 (−7.32%), 2013 (−5.24%), 2009 (−4.96%), and 2008 (−4.81%) in contrast to previous years. The predicted value for 2020–2050 follows the overall decrease trend, such as 61.59 m^3/inhabit/year in 2030, 44.78 m^3/inhabit/year in 2040, and 27.97 m^3/inhabit/year in 2050 (Fig. 26b).

Between 1970 and 2019, the weight of the total water withdrawal per capita in the total renewable water resources per capita recorded the maximum level of 1.91% in 1985 and the minimum level of 0.99% in 1970.

Particular for Luxembourg is that data is available starting with 1995 for the agricultural and industrial water withdrawal as percent of total water withdrawal and beginning with 1990 for the municipal water withdrawal as percent of total

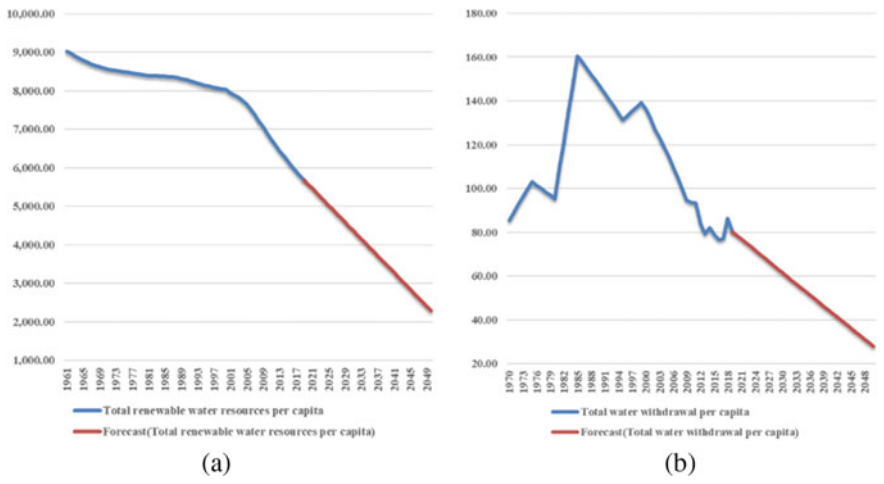

Fig. 26 Evolution and forecasting of Luxembourg's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1970 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

water withdrawal. The agricultural and industrial water withdrawal as percent of total water withdrawal registered the same evolution in 1996–2011 and 2016–2019 and the municipal water withdrawal as percent of total water withdrawal scored an opposed line. The highest boosts for the agriculture water withdrawal were in 2011 (+389.69%), 2015 (+137.5%), 2013 (+54.87%), 2017 (+29.82%), and 2019 (+27.06%), for the industrial water withdrawal in 2019 (+145.2%), 2014 (+41.78%), 2011 (+21.58%), 2017 (+19.84%), and 2012 (+12.02%), and for the municipal water withdrawal in 2013 (+3.76%), 2010 (+2.48%), 2009 (+2.13%), 2008 (+2.05%), and 2007 (+1.98%) against previous years. The highest declines for the agriculture water withdrawal were in 2016 (−56.76%), 2012 (−56.4%), 2010 (−9.23%), 2014 (−5.48%), and 2009 (−5.05%), for the industrial water withdrawal in 2013 (−44.19%), 2016 (−34.41%), 2015 (−32.14%), 2010 (−26.88%), and 2009 (−18.47%) and for the municipal water withdrawal in 2019 (−5.81%), 1995 (−3.54%), 1994 (−3.3%), 1993 (−3.09%), and 1992 (−2.89%) as compared to previous years (Fig. 27).

The foreseeable value of the agricultural and municipal water withdrawal as percent of total water withdrawal tracks an increasing trend and it is opposite to the industrial water withdrawal as percent of total water withdrawal. Thus, for the agricultural water withdrawal which scored 1.22% in 2019 and it is predicted a value of 1.29% in 2030, 1.61% in 2040, and 1.92% in 2050 (Fig. 27a). For the municipal water withdrawal, which registered 89.86% in 2019, it is projected a level of 96.7% in 2030, but starting with 2036 the level is higher than 100% and will not be possible to archive (Fig. 27c). Due to the height rate of reduction of the industrial water withdrawal until 2019, the expected values are below zero starting with 2020 and the forecast values until 2050 cannot be used (Fig. 27b).

2.14 Malta

The evolution of the total renewable water resources per capita, between 1961 and 2019, scored a reduction trend, which comprise three long decline periods (1962–1966, 1972–1995, and 1997–2019) and two short increase periods (1967–1971 and 1996). The highest drops were in 1995 (−67.64%), 2013 (−1.02%), 2012 (−0.97%), 2014 (−0.94%), and 1984–1987 and 1997–1998 (−0.91%) versus previous years. The highest rises were in 1996 (+203.77%), 1969 (+0.23%), 1968 (+0.21%), 1970 (+0.15%), and 1967 (+0.07%) as opposed to previous years. The forecast level for 2020–2050 is lower than the level from 2019 (114.68 m^3/inhabit/year), namely, 103.43 m^3/inhabit/year in 2030, 95.31 m^3/inhabit/year in 2040, and 87.18 m^3/inhabit/year in 2050 (Fig. 28a).

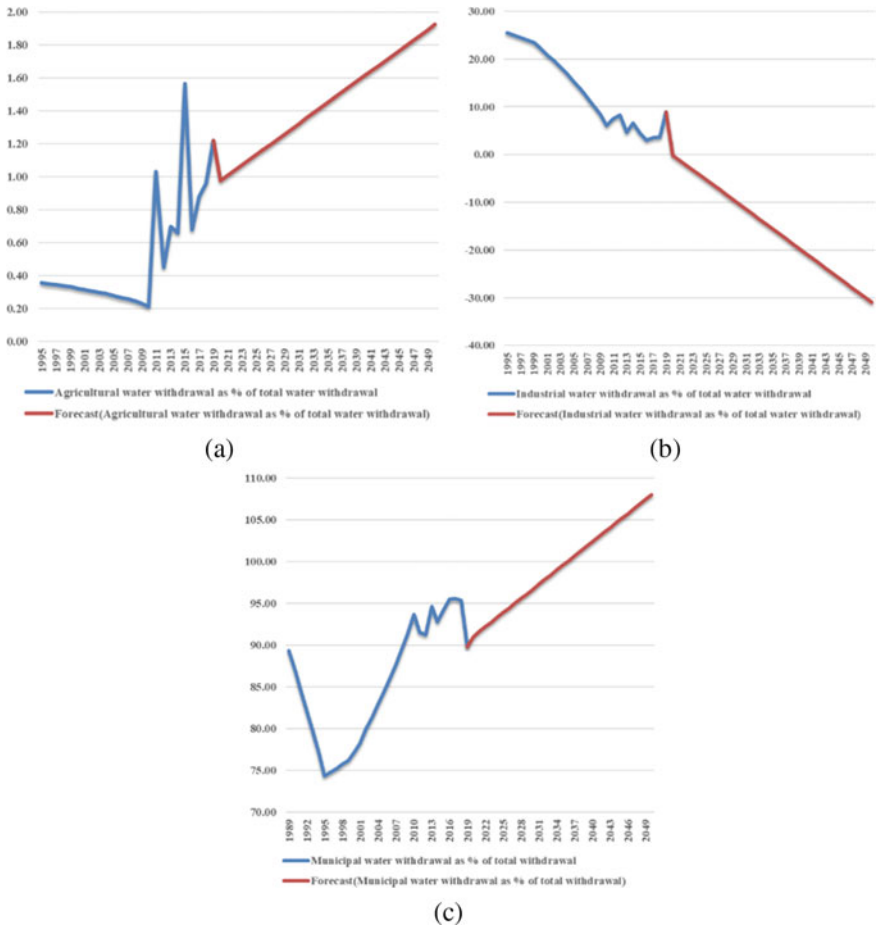

Fig. 27 Evolution and forecasting of Luxembourg's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1989 and 2050 (%). *Source* Made by author based on FAO (2022)

As regards the total water withdrawal per capita, data collected from AQUASTAT database cannot be analyzed due to the errors, i.e. the value of the total water withdrawal per capita is higher than the total renewable water resources per capita in 1993–2003 and 2014–2019 (Fig. 28b). Therefore, since the level of the agricultural, industrial and municipal water withdrawal as percent of total water withdrawal is based on the data of total water withdrawal per capita, it cannot be studied.

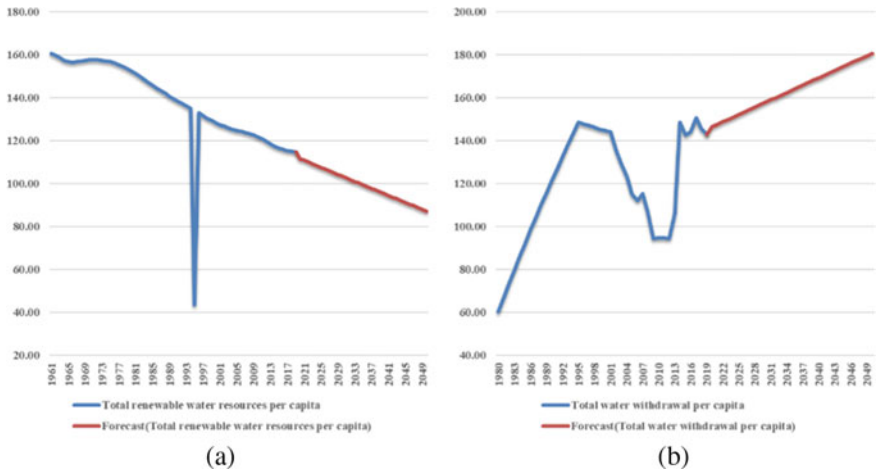

Fig. 28 Evolution and forecasting of Malta's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1980 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

2.15 The Netherlands

The analysis of the total renewable water resources per capita evolution, between 1961 and 2019, highlighted a constant reduction. The highest falls were in 1962 and 1963 (−1.36%), 1964 (−1.33%), 1965 (−1.3%), 1966 (−1.26%), and 1967 (−1.22%) against previous years. The expected value for 2020–2050 follows the same decrease trend, from 5,322.53 m^3/inhabit/year in 2019 to 5,194.03 m^3/inhabit/year in 2030, 5,077.24 m^3/inhabit/year in 2040, and 4,960,45 m^3/inhabit/year in 2050 (Fig. 29a).

As regards the evolution of the total water withdrawal per capita, it recorded both decline periods (1981–1996, 2006–2008, and 2011–2017) and boost periods (1997–2005, 2009–2010, and 2018–2019). The highest shrinks were in 2014 (−9.79%), 2013 (−8.35%), 2015 (−5.95%), 1996 (−5.47%), and 2016 (−4.85%), and the highest rises were in 2003 (+7.42%), 1997 (+6.83%), 2002 (+6.71%), 1998 (+6.33%), and 1999 (+5.89%) versus previous years. The forecast value for 2020–2050 tracks a decrease trend, for example 477.47 m^3/inhabit/year in 2030, 464.71 m^3/inhabit/year in 2040, and 451.94 m^3/inhabit/year in 2050 (Fig. 29b).

In 1980–2019, the weight of the total water withdrawal per capita in the total renewable water resources per capita fluctuated between 8.22% as minimum value (in 1998) and 12.69% as maximum value (in 2005).

There are partial similarities among the evolution of the agricultural, industrial, and municipal water withdrawal as percent of total water withdrawal, namely in 1997–2006 for the agricultural and municipal water withdrawal, in 2009–2017 for the agricultural and industrial water withdrawal. The municipal water withdrawal evolution was complete opposed to the industrial water withdrawal. The highest expands

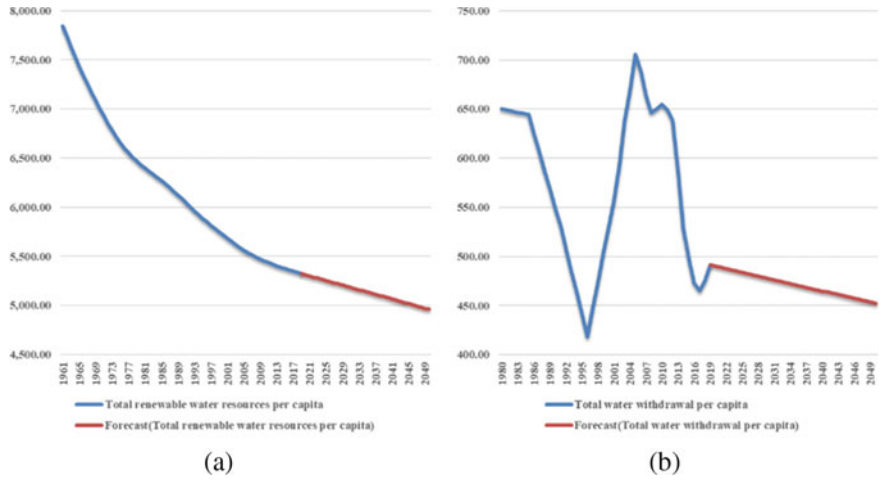

Fig. 29 Evolution and forecasting of the Netherlands' (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1980 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

for the agriculture water withdrawal were in 2003 (+192.34%), 2018 (+146.78%), 2013 (+93.16%), 2006 (+66.47%), and 2017 (+58.89%), for the industrial water withdrawal in 1997 (+2.52%), 2019 (+2.23%), 1998 (+2.14%), 1999 (+1.84%), and 2001 (+1.65%), and for the municipal water withdrawal in 2017 (+35.7%), 2018 (+13.5%), 2014 (+10.71%), 2013 (+9.22%), and 2015 (+7.16%) as compared to previous years. The highest drops for the agriculture water withdrawal were in 2004 (−50.04%), 2012 (−48.93%), 2001 (−42.95%), 2007 (−39.09%), and 2000 (−32.59%), for the industrial water withdrawal in 2016 (−9.08%), 2019 (−6.72%), 2013 (−1.78%), 2015 (−1.54%), and 2014 (−1.35%), and for the municipal water withdrawal in 2003 (−8.27%), 2002 (−7.66%), 2005 (−6.42%), 2004 (−6.14%), and 1997 (−6.1%) versus previous years (Fig. 30).

For 2020–2050 period, the predicted value of the agricultural and municipal water withdrawal as percent of total water withdrawal trails a fall trend, which is slightly in the case of the municipal water withdrawal. In contrast, the industrial water withdrawal as percent of total water withdrawal is expected to increase. Hence, the agricultural water withdrawal will record 2.49% in 2030, 2.02% in 2040, and 1.54% in 2050 (Fig. 30a). The municipal water withdrawal will register 23.27% in 2030, 23.15% in 2040, and 23.04% in 2050 (Fig. 30c). The industrial water withdrawal will score 73.81% in 2030, 74.02% in 2040, and 74.23% in 2050 (Fig. 30b).

Fig. 30 Evolution and forecasting of the Netherlands' (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1991 and 2050 (%). *Source* Made by author based on FAO (2022)

2.16 Poland

The evolution of the total renewable water resources per capita, between 1961 and 2019, can be described by one long decrease period (1962–1999) and one relatively long expand period (2000–2019) which was interrupted by a single fall in 2008. The highest drops were in 1962 (−1.23%), 1963 (−1.13%), 1964 (−1.04%), 1965 (−0.96%), and 1982 (−0.95%), and the highest rises were in 2013 and 2014 (+0.18%), 2012 (+0.16%), 2015 (+0.15%), 2003 and 2016 (+0.12%), and 2002 and

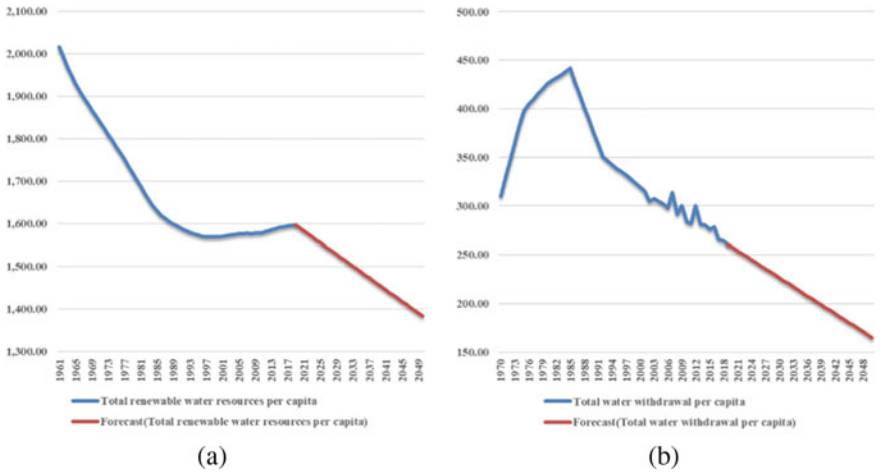

Fig. 31 Evolution and forecasting of Poland's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1970 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

2004 (+0.11%) as opposed to previous years. The forecast level for 2020–2050 tracks a diminish trend, from 1,596.82 m^3/inhabit/year in 2019 to 1,521.35 m^3/inhabit/year in 2030, 1,452.75 m^3/inhabit/year in 2040, and 1,384.14 m^3/inhabit/year in 2050 (Fig. 31a).

The total water withdrawal per capita scored an evolution in which the rise periods (1971–1985, 2003, 2007, 2009, 2012, and 2016) fluctuate with the decline periods (1986–2002, 2004–2006, 2008, 2010–2011, 2013–2015, and 2017–2019). The highest increases were in 2012 (+6.53%), 1971 (+5.95%), 1972 (+5.51%), 2007 (+5.27%), and 1973 (+5.12%) in contrast to previous years. The highest falls were in 2008 (−7.1%), 2013 (−6.48%), 2010 (−5.62%), 2017 (−4.64%), and 1992 (−3.41) contrary to previous years. The expected value for 2020–2050 follows the decrease trend started in 1986, such as 226.41 m^3/inhabit/year in 2030, 195.68 m^3/inhabit/year in 2040, and 164.96 m^3/inhabit/year in 2050 (Fig. 31b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 1970 and 2019, registered the maximum level of 27.12% in 1985 and the minimum level of 16.3% in 2019.

For agricultural water withdrawal as percent of total water withdrawal, data is available starting with 1970 and for industrial and municipal water withdrawal as percent of total water withdrawal, data is provided beginning with 1992. The agricultural and municipal water withdrawal as percent of total water withdrawal registered the same evolution in 1993–2000, 2002–2013, and 2016–2019. The industrial water withdrawal as percent of total water withdrawal recorded an opposite evolution against the agricultural and municipal water withdrawal in 1993–2000, 2003–2006, 2011, and 2017–2019 (Fig. 32).

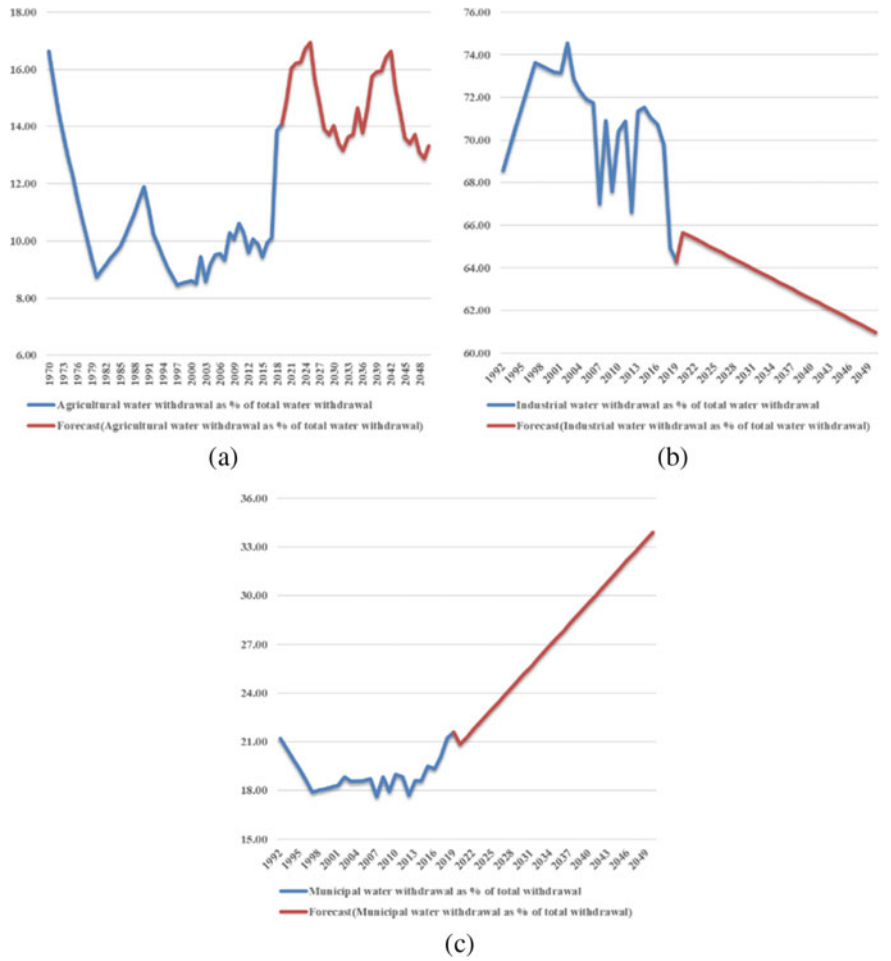

Fig. 32 Evolution and forecasting of Poland's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1970 and 2050 (%). *Source* Made by author based on FAO (2022)

The highest increases for the agriculture water withdrawal were in 2018 (+37.12%), 2002 (+10.97%), 2008 (+10.22%), 2004 (+6.49%), and 2010 (+5.47%), for the industrial water withdrawal in 2013 (+7.1%), 2008 (+5.81%), 2010 (+4.16%), 2002 (+1.87%), and 1994 and 1995 (+1.49%), and for the municipal water withdrawal in 2008 (+6.77%), 2010 (+5.76%), 2018 (+5.5%), 2015 (+4.84%), and 2017 (+4.05%) against previous years. The highest diminishes for the agriculture water withdrawal were in 2003 (−9.02%), 1992 (−7.69%), 1980 (−6.89%), 1994 and 2012 (−6.74%), and 1979 (−6.71%), for the industrial water withdrawal in 2018 (−6.96%), 2007 (−6.59%), 2012 (−6%), 2009 (−4.68%), and 2003 (−2.23%) and for the municipal water withdrawal in 2012 (−6.07%), 2007 (−5.76%), 2009

(−4.68%), 1997 (−3.76%), and 1996 (−3.57%) as compared to previous years (Fig. 32).

For 2020–2050 period, the possible value of the agricultural water withdrawal as percent of total water withdrawal tracks a oscillate trend with values of 14.2% in 2030, 15.96% in 2040, and 13.30% in 2050 (Fig. 32a). The predicted value of the industrial water withdrawal as percent of total water withdrawal follows the overall decline trend of 64.09% in 2030, 62.53% in 2040, and 60.97% in 2050 (Fig. 32b). Opposite, the expected value of the municipal water withdrawal as percent of total water withdrawal trails an increase trend of 25.21% in 2030, 29.56% in 2040, and 33.91% in 2050 (Fig. 32c).

2.17 Slovakia

The analysis of the total renewable water resources per capita evolution, between 1961 and 2019, underscores an overall reduction trend. There are two fall periods (1994–2002 and 2007–2019) and one growth period (2003–2006, in which the rise was 0.01% in each year). The highest falls were in 1994 (−0.29%), 1995 (−0.23%), 1996 (−0.17%), 2013–2015 (−0.13%), and 1997 and 2016 (−0.12%), against previous years. The expected value for 2020–2050 follows the same decrease trend with a constant reduction value of 0.06% per year, from 9,180.85 m^3/inhabit/year in 2019 to 9,124.32 m^3/inhabit/year in 2030, 6,072.74 m^3/inhabit/year in 2040, and 9,021.17 m^3/inhabit/year in 2050 (Fig. 33a).

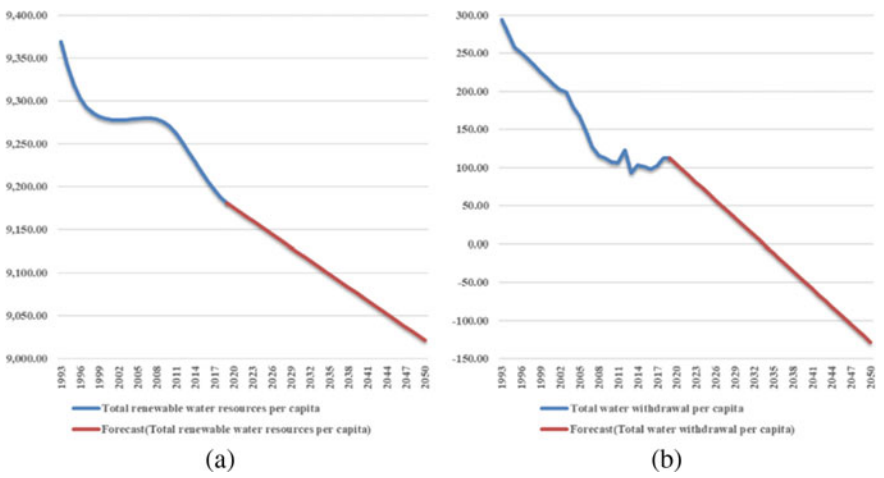

Fig. 33 Evolution and forecasting of Slovakia's (**a**) total renewable water resources per capita and (**b**) total water withdrawal per capita between 1993 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

In the case of the evolution of the total water withdrawal per capita, it recorded the same decreasing trend with four decline periods (1994–2011, 2013, 2015–2016, and 2019) and short expand periods (therefore there are only four increases +15.82% in 2012, +10.76% in 2014, +9.91% in 2018, and +3.87% in 2017). The highest shrinks were in 2013 (−24.3%), 2007 (−14.25%), 2006 (−11.51%), 2004 (−10.19%), and 2008 (−9.43%) as opposed to previous years. The estimate level for 2020–2050 tracks a decrease trend, from 112.15 m^3/inhabit/year in 2019 to 26.87 m^3/inhabit/year in 2023. Starting with 2034, the level cannot be use because is negative and is not possible to be recorded (Fig. 33b).

In 1993–2019, the weight of the total water withdrawal per capita in the total renewable water resources per capita declined significantly, from 3.14% in 1993, which was the highest value, to 1.01% (the lowest value) in 2013 and 1.22% in 2019.

The agricultural and municipal water withdrawal as percent of total water withdrawal scored the same evolution in 1996–2002, 2008–2009, and 2013–2015. Furthermore, the industrial water withdrawal as percent of total water withdrawal recorded an opposed evolution compared to the agricultural water withdrawal in 1994–2004, 2006, 2008–2011, 2013–2014, and 2016–2018. The highest expands for the agriculture water withdrawal were in 2018 (+133.29%), 2003 (+62.03%), 2009 (+51%), 2017 (+46.11%), and 2015 (+34.77%), for the industrial water withdrawal in 2012 (+14.44%), 2014 (+13.69%), 1997 (+4.41%), 1996 (+4.35%), and 2001 (+3.81%), and for the municipal water withdrawal in 2013 (+27.22%), 2007 (+13.35%), 2006 (+9.93%), 2004 (+7.98%), and 2005 (+3.21%) as compared to previous years. The highest declines for the agriculture water withdrawal were in 2004 (−61.05%), 2016 (−29.54%), 2010 (−26.02%), 2001 (−20.89%), and 2005 (−19.41%), for the industrial water withdrawal in 2013 (−26.33%), 2007 (−11.71%), 2006 (−9.07%), 2018 (−6.27%), and 2009 (−5.91%), and for the municipal water withdrawal in 2014 (−12.83%), 2012 (−12.78%), 2018 (−9.41%), 1997 (−3.97%), and 1996 (−3.62%) versus previous years (Fig. 34).

The projected value for 2020–2050 in the case of the agricultural and municipal water withdrawal as percent of total water withdrawal tracks a rise trend, which is contrary to the industrial water withdrawal as percent of total water withdrawal. Thus, the agricultural water withdrawal as percent of total water withdrawal will score 13.38% in 2030, 13.5% in 2040, and 13.62% in 2050 (Fig. 34a); the municipal water withdrawal will register 55.46% in 2030, 62.43% in 2040, and 69.4% in 2050 (Fig. 34c); the industrial water withdrawal will score 38.98% in 2030, 23.8% in 2040, and 16.61% in 2050 (Fig. 34b).

2.18 Slovenia

The evolution of the total renewable water resources per capita, between 1992 and 2019, shows two short expand periods (1993–1997 and 2001–2002) and two decline periods of which one is rather long (1999–2000 and 2003–2019). The highest rises were in 1994 (+0.26%), 1993 (+0.24%), 1995 (+0.21%), 1996 (+0.13%), and

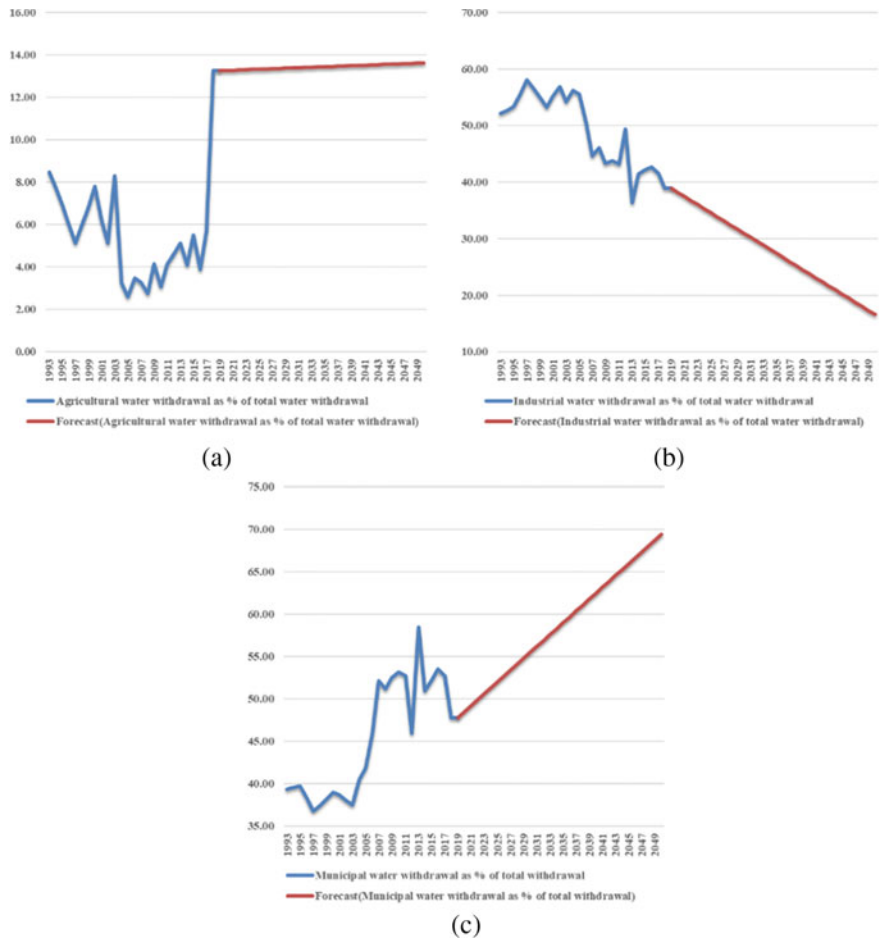

Fig. 34 Evolution and forecasting of Slovakia's (a) agricultural, (b) industrial, and (c) municipal water withdrawal as % of total water withdrawal, between 1993 and 2050 (%). *Source* Made by author based on FAO (2022)

1997 (+0.06%), and the highest drops were in 2008 (−0.54%), 2009 (−0.53%), 2007 (−0.48%), 2010 (−0.47%), and 2011 (−0.39%) as opposed to previous years. The forecast level for 2020–2050 tracks a diminish trend with a relatively constant decrease rate of 0.2% per year, from 15,332.04 m^3/inhabit/year in 2019 to 15,008.48 m^3/inhabit/year in 2030, 14,714.39 m^3/inhabit/year in 2040, and 14,420.3 m^3/inhabit/year in 2050 (Fig. 35a).

The total water withdrawal per capita scored an evolution in which each of the three rise periods (2003–2006, 2013, and 2017–2018) was followed by a decline period (2007–2012, 2014–2016, and 2019). The highest increases were in 2013 (+24.19%), 2017 (+4.86%), 2018 (+3.11%), 2003 (+1.01%), and 2004 (+0.74%),

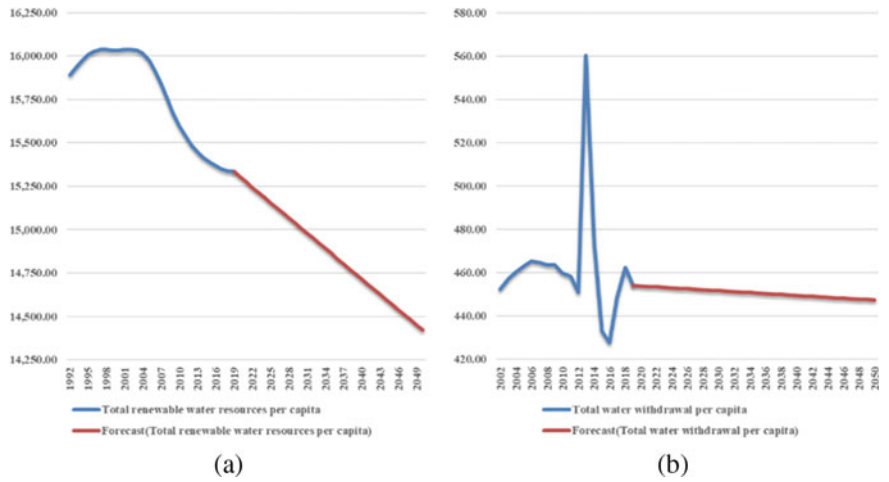

Fig. 35 Evolution and forecasting of Slovenia's (**a**) total renewable water resources per capita between 1992 and 2050 and (**b**) total water withdrawal per capita between 2002 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

and the highest falls were in 2014 (−15.35%), 2015 (−8.66%), 2019 (−1.81%), 2016 (−1.22%), and 2003 (−1.01) in contrast to previous years. The expected value for 2020–2050 follows the decrease trend started with a fixed fall rate of 0.05% per year, such as 451.73 m^3/inhabit/year in 2030, 449.53 m^3/inhabit/year in 2040, and 447.34 m^3/inhabit/year in 2050 (Fig. 35b).

The weight of the total water withdrawal per capita in the total renewable water resources per capita, between 2002 and 2019, registered slightly variations, namely 2.78% (as minimum level in 2016) and 3.63% (in maximum level in 2013).

Particular for Slovenia is that the available data for the agricultural, industrial, and municipal water withdrawal as percent of total water withdrawal starts in 2002. The agricultural and municipal water withdrawal as percent of total water withdrawal recorded a similar evolution in 2003–2006, 2008, 2011–2012, 2015–2016, and 2018–2019. The industrial water withdrawal as percent of total water withdrawal recorded an opposite evolution against the agricultural and municipal water withdrawal in 2002–2006, 2008–2016, and 2018–2019 (Fig. 36).

The highest increases for the agriculture water withdrawal were in 2006 (+171.42%), 2015 (+139.06%), 2011 (+99.82%), 2013 (+25.71%), and 2017 (+12.59%), for the industrial water withdrawal in 2013 (+3.85%), 2005 (+1.55%), 2004 (+1.54%), 2003 (+1.41%), and 2012 (+0.81%), and for the municipal water withdrawal in 2014 (+17.24%), 2015 (+10.16%), 2011 (+1.65%), 2019 (+1.21%), and 2010 (+1.01%) against previous years. The highest diminishes for the agriculture water withdrawal were in 2005 (−50.39%), 2014 (−47.61%), 2010 (−35.77%), 2004 (−28.73%), and 2007 (−27.2%), for the industrial water withdrawal in 2014

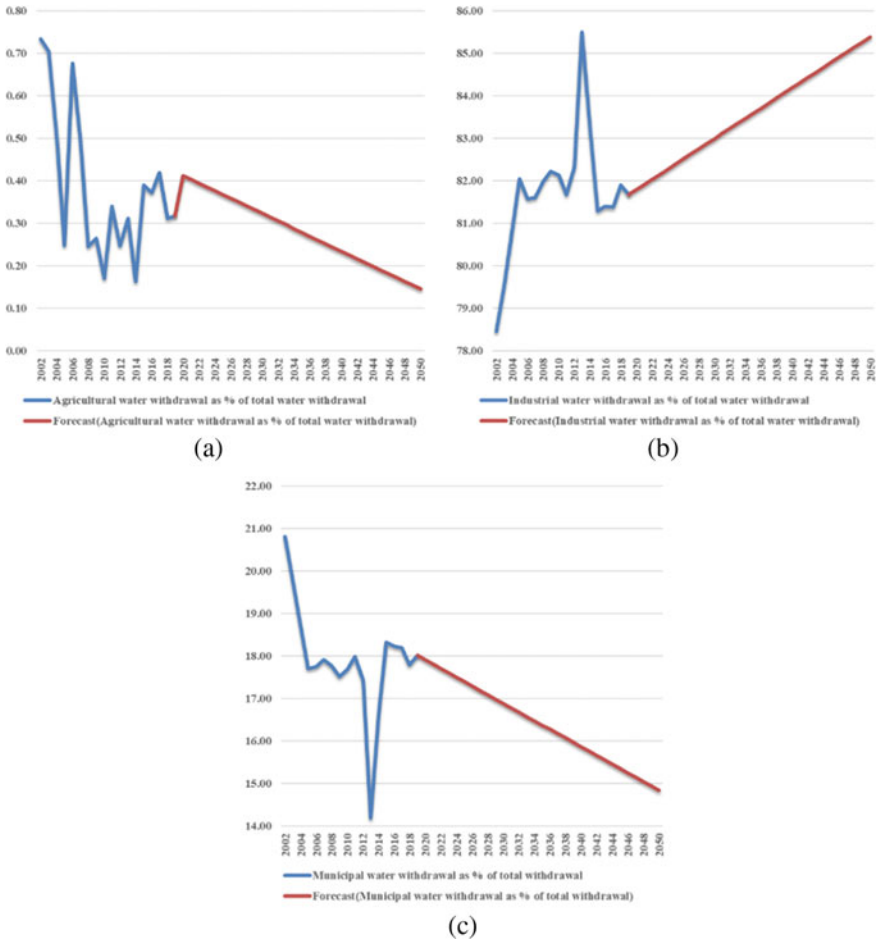

Fig. 36 Evolution and forecasting of Slovenia's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 2002 and 2050 (%). *Source* Made by author based on FAO (2022)

(−2.69%), 2015 (−2.29%), 2006 (−0.58%), 2011 (−0.56%), and 2019 (−0.27%) and for the municipal water withdrawal in 2013 (−18.54%), 2005 (−5.34%), 2004 (−5.2%), 2003 (−5.19%), and 2012 (−3.15%) as compared to previous years (Fig. 36).

For 2020–2050 period, the predicted value of the agricultural water withdrawal as percent of total water withdrawal tracks a decrease trend with values of 0.32% in 2030, 0.23% in 2040, and 0.15% in 2050 (Fig. 36a). The same trend is followed by the municipal water withdrawal as percent of total water withdrawal for example,

16.89% in 2030, 15.87% in 2040, and 14.85% in 2050 (Fig. 36c). Opposite, the probable value of the industrial water withdrawal as percent of total water withdrawal scores an increase trend of 82.99% in 2030, 84.19% in 2040, and 85.39% in 2050 (Fig. 36b).

2.19 Spain

The analysis of the total renewable water resources per capita evolution, between 1961 and 2019, emphasizes a general reduction trend with two fall periods (1962–2011and 2017–2019) and one growth five years period (+0.05% in 2012, +0.28% in 2013, +0.33% in 2013, +0.23% in 2014, and +0.08% in 2016), and the highest falls were in 2004 (−1.64%), 2005 (−1.61%), 2003 and 2006 (−1.59%), 2002 (−1.43%), and 2007 (−1.54%) against previous years. The expected value for 2020–2050 follows the same decrease trend, from 2,385.7 m^3/inhabit/year in 2019 to 2,150.83 m^3/inhabit/year in 2030, 1,942.98 m^3/inhabit/year in 2040, and 1,735.13 m^3/inhabit/year in 2050 (Fig. 37a).

As regards of the evolution of the total water withdrawal per capita, it recorded a decreasing trend as well with both six expand periods (1976–1986, 1998–2000, 2005, 2009, and 2014) and six decline periods (1987–1997, 2001–2004, 2006–2008, 2011–2012, 2013, and 2015–2019). The highest boosts were in 2012 (+4.63%), 2005 (+3.67%), 1985 (+2.02%), 1984 (+2.01%), and 1983 and 2014 (+1.99%), and the highest shrinks were in 2013 (−11.56%), 2006 (−6.36%), 1991 (−4.86%), 1990 (−4.63%), and 1989 (−4.43%) as opposed to previous years. The estimate level

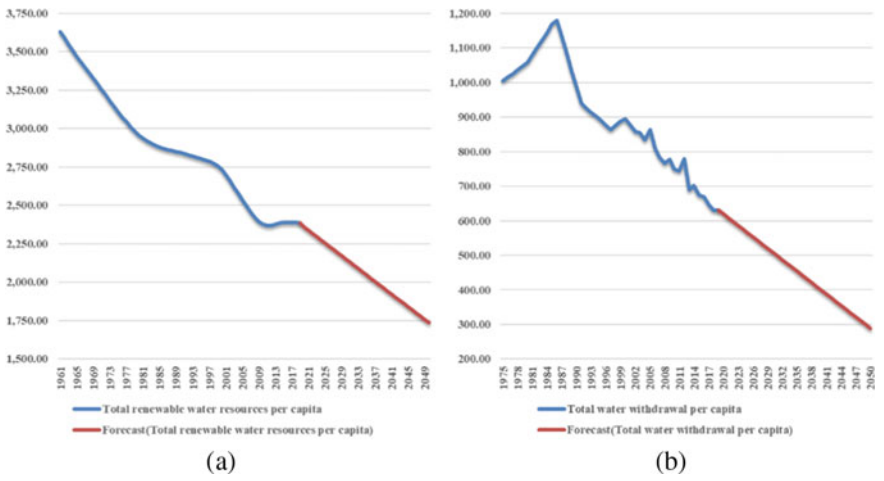

Fig. 37 Evolution and forecasting of Spain's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1975 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

for 2020–2050 tracks a decrease trend, from 630.53 m^3/inhabit/year in 2019 to 509 m^3/inhabit/year in 2030, 398.53 m^3/inhabit/year in 2040, and 288.05 m^3/inhabit/year in 2050 (Fig. 37b).

In 1975–2019, the weight of the total water withdrawal per capita in the total renewable water resources per capita declined, from 32.36% in 1975 to 26.43% in 2019 (which was lowest value), taking into account that the highest value of 41.12% was recorded in 1986.

The agricultural and municipal water withdrawal as percent of total water withdrawal registered the same evolution in 1987–1989, 1994–2001, 2002–2003, 2005–2006, 2008–2012, 2014–2016, and 2018. The industrial water withdrawal as percent of total water withdrawal recorded an opposed evolution compared to the agricultural water withdrawal in 1986–1991, 1998–2002, 2004–2005, 2007–2009, 2011–2014, and 2017–2018. The highest expands for the agriculture water withdrawal were in 2009 (+2.59%), 2012 (+2.76%), 2005 (+2.08%), 2011 (+2%), and 2014 (+1.75%) for the industrial water withdrawal in 2013 (+11.38%), 2008 (+4.59%), 2018 (+4.42%), 2010 (+3.37%), and 2001 (+2.35%), and for the municipal water withdrawal in 1997 (+8.59%), 1995 (+8.17%), 2009 (+7.28%), 2010 (+6.64%), and 2011 (+6.09%) as compared to previous years. The highest diminishes for the agriculture water withdrawal were in 2013 (−5.49%), 2015 (−1.64%), 1998 (−1.44%), 1999 (−1.41%), and 2000 (−1.38%), for the industrial water withdrawal in 1991 (−10.57%), 1990 (−8.79%), 1989 (−7.45%), 1988 (−6.4%), and 2012 (−6.11%) and for the municipal water withdrawal in 1993 (−12.38%), 2015 (−8.27%), 2019 (−8.23%), 2016 (−8.22%), and 2018 (−8.2%) versus previous years (Fig. 38).

For 2020–2050, the forecast of the agricultural water withdrawal as percent of total water withdrawal follows an increase trend and the industrial and municipal water withdrawal as percent of total water withdrawal tracks an opposed trend. Therefore, the agricultural water withdrawal as percent of total water withdrawal will score 66.21% in 2030, 66.99% in 2040, and 67.77% in 2050 (Fig. 38a), the industrial water withdrawal will record 18.62% in 2030, 17.9% in 2040, and 17.19% in 2050 (Fig. 38b), and the municipal water withdrawal will register 15.2% in 2030, 15.14% in 2040, and 15.7% in 2050 (Fig. 38c).

2.20 Sweden

The evolution of the total renewable water resources per capita, between 1961 and 2019, illustrates a continuous fall trend. The highest drops were in 1967 (−0.85%), 1968 (−0.84%), 2009–2010 (−0.82%), 1966 and 2011 (−0.81%), and 2008 and 2012 (−0.8%) as opposed to previous years. The predicted level for 2020–2050 tracks a diminish trend, from 17,336.93 m^3/inhabit/year in 2019 to 15,473.34 m^3/inhabit/year in 2030, 13,780.77 m^3/inhabit/year in 2040, and 12,190.54 m^3/inhabit/year in 2050 (Fig. 39a).

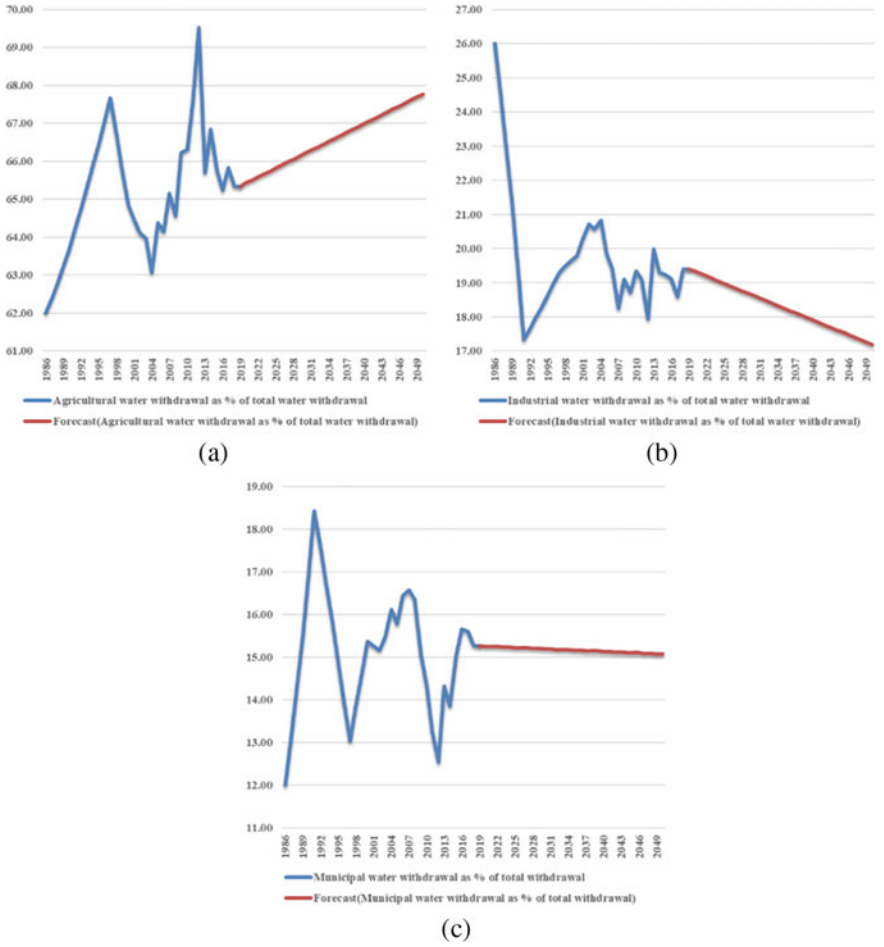

Fig. 38 Evolution and forecasting of Spain's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1986 and 2050 (%). *Source* Made by author based on FAO (2022)

As for the total water withdrawal per capita, its evolution recorded a drop trend as well, with two decline periods of which one is rather long (1971–1972 and 1976–2019) and only one short increase period (+0.01% in 1973, +0.03% in 1974, and +0.01% in 1975). The highest falls were in 1985 (−7.3%), 1984 (−6.72%), 1983 (−6.26%), 1982 (−5.9%), and 1981 (−5.64) versus previous years. The expected value for 2020–2050 follows the decrease trend, such as 170.63 m^3/inhabit/year in 2030, 111.07 m^3/inhabit/year in 2040, and 51.51 m^3/inhabit/year in 2050 (Fig. 39b).

Between 1970 and 2019, the weight of the total water withdrawal per capita in the total renewable water resources per capita registered a reduction trend from 2.34% in 1970 to 1.36% (as minimum level) in 2019. The maximum level of 2.38% was scored in 1975.

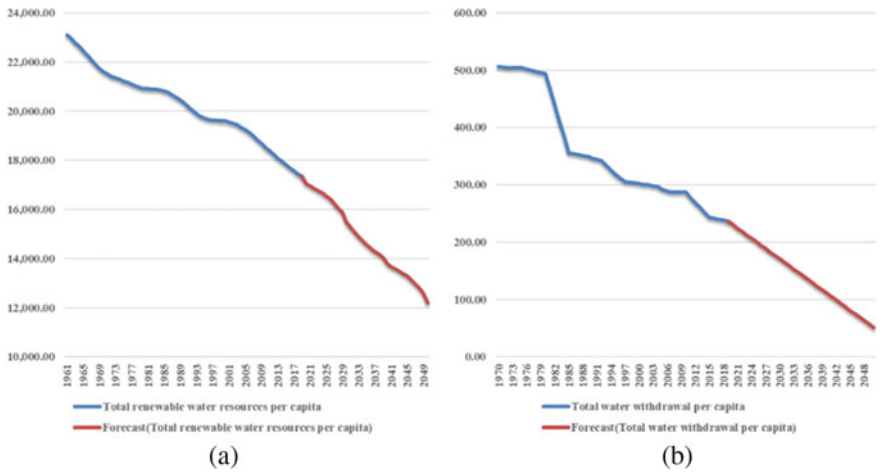

Fig. 39 Evolution and forecasting of Sweden's (**a**) total renewable water resources per capita between 1961 and 2050 and (**b**) total water withdrawal per capita between 1970 and 2050 (m^3/inhabit/year). *Source* Made by author based on FAO (2022)

The agricultural, industrial, and municipal water withdrawal as percent of total water withdrawal recorded a constant evolution in 1981–1985, 2006–2008, and 2016–2019. The agricultural water withdrawal as percent of total water withdrawal scored a similar evolution comparted to the municipal water withdrawal in the first half of the period (1971–1975 and 1986–1989), and in contrast to the industrial water withdrawal in the second half of the period (1993–1995, 1998–200, 2002–2004, and 2011–2015). The industrial water withdrawal as percent of total water withdrawal recorded an opposite evolution against the municipal water withdrawal for long periods, namely 1971–1990 and 1993–2015 (Fig. 40).

The highest increases for the agriculture water withdrawal were in 1986 (+14.22%), 1987 (+12.45%), 1988 (+11.06%), 1989 (+9.96%), and 1991 (+4.3%), for the industrial water withdrawal in 2005 (+1.74%), 2003 and 2004 (+0.67%), 2001 (+0.5%), 2008 and 2009 (+0.32%), and 2010 (+0.31%), and for the municipal water withdrawal in 1986 (+10.39%), 1987 (+9.41%), 1988 (+8.6%), 1989 (+7.91%), and 1995 (+2.69%) against previous years. The highest diminishes for the agriculture water withdrawal were in 2005 (−19.72%), 2001 (−9.55%), 2010 (−3.68%), 2009 (−3.6%), and 2008 (−3.53%), for the industrial water withdrawal in 1989 (−4.8%), 1988 (−4.59%), 1987 (−4.39%), 1986 (−4.21%), and 1997 (−1.81%) and for the municipal water withdrawal in 2004 (−1.01%), 2003 (−1%), 1992 (−0.56%), 1991 (−0.55%), and 1990 (−0.35%) as compared to previous years (Fig. 40).

For 2020–2050 period, the predicted value of the agricultural water withdrawal as percent of total water withdrawal tracks a growth trend with values of 3.23% in 2030, 3.29% in 2040, and 3.35% in 2050 (Fig. 40a). The same trend is followed by the municipal water withdrawal as percent of total water withdrawal for example, 42.21% in 2030, 44.03% in 2040, and 45.85% in 2050 (Fig. 40c). Conversely, the

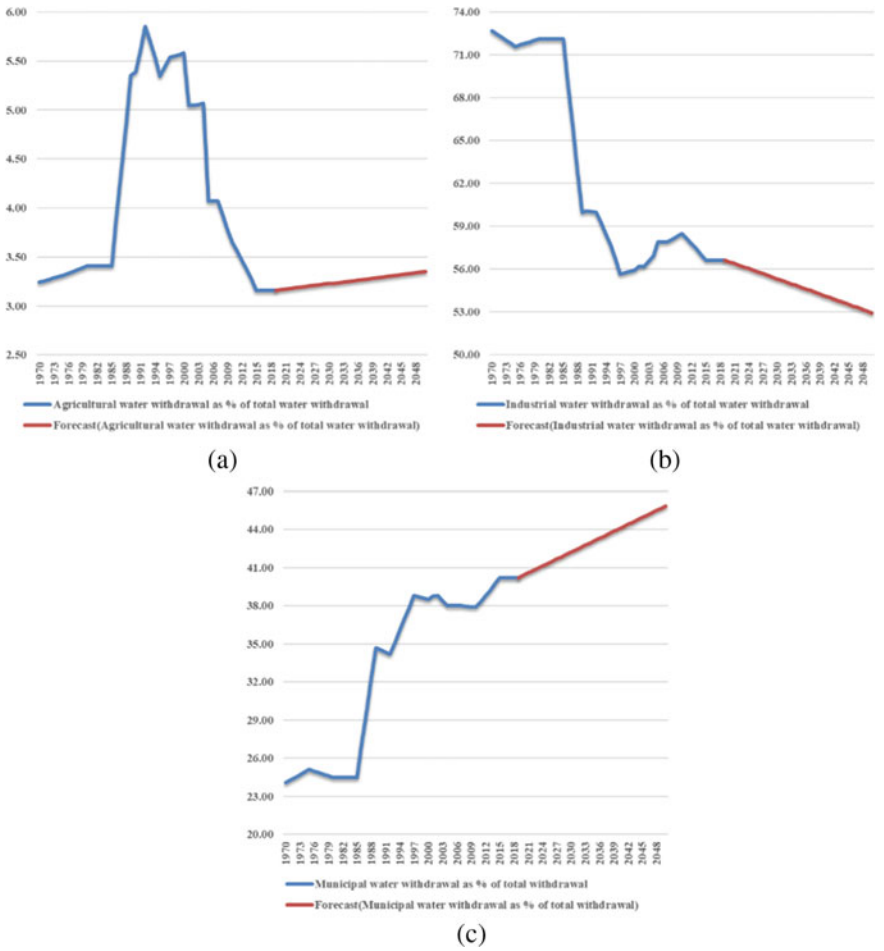

Fig. 40 Evolution and forecasting of Sweden's (**a**) agricultural, (**b**) industrial, and (**c**) municipal water withdrawal as % of total water withdrawal, between 1970 and 2050 (%). *Source* Made by author based on FAO (2022)

probable value of the industrial water withdrawal as percent of total water withdrawal recorded a decline trend of 55.32% in 2030, 54.13% in 2040, and 52.94% in 2050 (Fig. 40b).

2.21 Results and Discussions

The weight of the total water withdrawal per capita in the total renewable water resources per capita as an indicator describes the country's abstraction capability

from the water resources. Therefore, there is a single state which increased its weight (Cyprus), while few countries maintained it relatively constant (Austria, Ireland, Luxembourg, and Slovenia), and many states recorded a decrease in their weight (Belgium, Bulgaria, Czechia, Denmark, Finland, France, Germany, Italy, the Netherlands, Poland, Slovakia, Spain, and Sweden).

By analyzing the same indicator with respect to the average value calculated in each year based on the level recorded by every state, two country groups can be outlined. The first includes countries with a weight lower than the average value, namely Austria, Czechia, Denmark, Finland, France, Ireland, Luxembourg, the Netherlands, Slovakia, Slovenia, and Sweden. The second group consists of countries with a weight higher than the average value, as follows: Belgium, Bulgaria, Cyprus, Germany, Italy, Poland, and Spain.

An additional scale of the top 5 countries can be pointed out based on the same indicator calculated as an average value of each country taking into account all the values of the state's specific reporting period. Thus, the countries with the highest weight of the total water withdrawal per capita in the total renewable water resources per capita were Belgium (38.34%), Bulgaria (38.24%), Spain (33.14%), Cyprus (27.42%), and Germany (25.72%). Conversely, the countries with the lowest weight were Luxembourg (1.46%), Sweden (1.77%), Slovakia (1.8%), Ireland (2.04%), and Finland (2.67%). Slovenia (2.96%) and Austria (4.56%) were not far from the top 5 low values.

Relying on the scatter of the agricultural water withdrawal as percent of total water withdrawal values of each country, graph analysis emphasizes two major country clusters. The first cluster consists of states with level higher than 20% and it includes Cyprus, Denmark, Italy, and Spain. The second cluster comprises the states with a level lower than 20%, namely: Austria, Belgium, Bulgaria, Czechia, Finland, France, Germany, Ireland, Luxembourg, the Netherlands, Poland, Slovakia, Slovenia, and Sweden.

The same countries are part of the same two country clusters which occur by grouping the states in relation with their value of the agricultural water withdrawal as percent of total water withdrawal against the average value calculated in each year as regards the level scored by every state. The countries from the first cluster registered a level higher than the year average value and vice versa.

By comparing the average value of each country in line with all the values of the state specific reporting period, the top 5 countries with the highest agricultural water withdrawal as percent of total water withdrawal were: Cyprus (73.54%), Spain (65.19%), Italy (49.34%), Denmark (36.38%), and Bulgaria (18.56%). By contrast, the top 5 countries with the lowest agricultural water withdrawal as percent of total water withdrawal were: Slovenia (0.38%), Luxembourg (0.51%), Germany (1.15%), the Netherlands (1.69%), and Czechia (1.71%).

The graph analysis of the countries' industrial water withdrawal as percent of total water withdrawal exhibits two country clusters. The first cluster comprises the states with a level higher than 50%, such as Austria, Belgium, Bulgaria, Czechia, Finland, France, Germany, the Netherlands, Poland, Slovenia, and Sweden. The second cluster

encloses the states with a level lower than 50%, namely: Cyprus, Denmark, Ireland, Italy, Luxembourg, Slovakia, and Spain.

The distribution of the countries into two groups according to the value of the industrial water withdrawal as percent of total water withdrawal as compared to the average value computed each year as regards the level recorded by every state shows that the first group which registered a level higher than the annual average comprises the same countries from the first cluster according to the previous sorting. The reverse situation is also valid.

The top 5 countries with the highest average value in line with all the values of the state specific reporting period were Belgium (86.8%), the Netherlands (82.87%), Slovenia (81.71%), Austria (78.01%), and Finland (74.92%), whereas the states that recorded the lowest average value were Cyprus (2.5%), Denmark (10.85%), Luxembourg (13.46%), Spain (19.72%), and Italy (29.59%).

As for the municipal water withdrawal as percent of total water withdrawal, the graph analysis of its scatter values highlights two country groups and the boundary of 40%. The first group includes the states with a level higher than 40%, such as Denmark, Ireland, Luxembourg, and Slovakia, and the second group includes the states with a level lower than 40%, in particular Austria, Belgium, Bulgaria, Cyprus, Czechia, Finland, France, Germany, Italy, the Netherlands, Poland, Slovenia, Spain, and Sweden.

Given the value of the municipal water withdrawal as percent of total water withdrawal in contrast to the average value computed in each year as regards the level recorded by every state, two main groups stand out. The first group consists of countries with a value lower than the average value, i.e. Austria, Belgium, Bulgaria, Cyprus (only until 2012), Finland, France, Germany (only until 2011), Italy, the Netherlands, Poland, Slovenia, and Spain. The second group scored a value higher than the average value, for example Czechia, Denmark, Ireland, Luxembourg, Slovakia, and Sweden.

The top 5 countries with the highest average value based on all the values of the state specific reporting period were Luxembourg (85.47%), Denmark (52.9%), Ireland (52.39%), Slovakia (45.27%), and Czechia (37.84%), and the states with the lowest average value were Belgium (11.86%), Bulgaria (14.24%), Spain (15.1%), Slovenia (17.91%), and France (18%).

3 Conclusions

The analysis of the 27 EU countries' average total renewable water resources per capita related to the EU's average total renewable water resources per capita shows that 76.19% of the 27 EU countries registered a level lower than the EU's average level. Moreover, 68.75% of these countries (such as Belgium, Bulgaria, Cyprus, Czechia, Denmark, France, Germany, Italy, Malta, Poland, and Spain) recorded less than half of the EU's average level (4,058.24 m^3/inhabit/year). The 27 EU countries could be grouped into 4 clusters. The first cluster of countries is characterized by a very high level above the EU's average which is the case of Croatia, Finland,

Ireland, Latvia, Slovenia, and Sweden. The second cluster of countries recorded a level which hardly exceeds the EU's average level (Austria, Estonia, Hungary, Romania, and Slovakia). The third cluster of countries registered a level slightly below the EU's average and includes Greece, Lithuania, Luxemburg, and Portugal. The fourth cluster of countries scored a very low level, below the EU's average, such as Belgium, Bulgaria, Cyprus, Czechia, Denmark, France, Germany, Italy, Malta, Poland, and Spain.

Concerning the EU countries' evolution trend of total renewable water resources per capita between 1961 and 2019, 14.82% of EU member states showed an increasing trend throughout the 1961–2019 period, 22.22% of them registered a growth trend at the end of the period, and 62.96% of countries recorded a continuous diminish trend.

There are 9 countries that recorded both the lowest level of the average total renewable water resources per capita in contrast to the EU's average of total renewable water resources per capita, and a decreasing trend of the total renewable water resources per capita, namely Belgium, Cyprus, Czechia, Denmark, France, Germany, Italy, Malta, and Spain.

As regards the 19 EU countries that were selected for analysis due to the lowest level of the average total renewable water resources per capita in contrast to the EU's average of total renewable water resources per capita and/or due to the decreasing trend of the total renewable water resources per capita throughout their specific period of time, each state scored different ranks concerning the indicators.

According to the scatter of the total renewable water resources per capita values, there are two main country groups. The first group comprises the countries that recorded a value higher than 5,000 m^3/inhabit/year, which is the case of Ireland, Finland, Slovenia, and Sweden. Conversely, the second group scored a value lower than 5,000 m^3/inhabit/year, i.e. Austria, Belgium, Bulgaria, Cyprus, Czechia, Denmark, France, Germany, Italy, Luxembourg, Malta, the Netherlands, Poland, Slovenia, and Spain.

As for the total water withdrawal per capita, the values are gathered below 400 m^3/inhabit/year (for example, Cyprus, Czechia, Denmark, Ireland, Luxembourg, Poland, Slovakia, and Sweden) and beyond 400 m^3/inhabit/year (for instance, Bulgaria, Finland, France, Italy, the Netherlands, Slovenia, and Spain). In a particular case are the countries such as Austria, Belgium, and Germany which recorded values higher than 400 m^3/inhabit/year in the first three-quarters of the analyzed period and lower than 400 m^3/inhabit/year in the last years.

Luxembourg and Slovakia recorded the lowest level of the total water withdrawal per capita of 80.07 m^3/inhabit/year and 112.15 m^3/inhabit/year, respectively, in 2019. This situation is alarming whereas the forecast level for the next 10 years follows a declining trend. Additionally, these two countries as well as Sweden scored the lowest weight of the total water withdrawal per capita in the total renewable water resources per capita.

The comparison of the average level of the agricultural, industrial, and municipal water withdrawal as percent of total water withdrawal computed based on the average value of each of the 18 analyzed countries highlights that industrial water withdrawal

recorded the highest level of 55.66%, the municipal water withdrawal scored 29.32%, and agricultural water withdrawal registered 16.88%. Thus, on average, more than a half of the water withdrawal is used by the industrial sector. The transition to the green economy by using hydro in a higher proportion as compared to the other renewable energy (solid biofuels, biogases, liquid biofuels, geothermal, solar thermal, solar photovoltaic, tide, wave, ocean, and wind) will increase the focus on the water resources and the industrial water withdrawal as percent of total water withdrawal will rise beyond the average level above mentioned. The growth of the industrial water withdrawal weight in the total water withdrawal will generate that the agriculture and municipal water withdrawal to diminish their weight, with negative impact on crop production, further on feed and food production. Therefore, the transition from using coal, oil and gas resources to renewable resources must be done both gradually, smoother and through multiple periodic assessments of their economic and social impact.

The forecast level of the total renewable water resources per capita for 2020–2050 underscores that 18 out of 19 analyzed countries record a decrease trend. Bulgaria is the only state that is expected to rise its total renewable water resources per capita. Concerning the total water withdrawal per capita, the reduction trend is identified to all 18 countries (Malta is not included due to the data error).

The expected value of the agricultural water withdrawal as percent of total water withdrawal for 2020–2050 emphasizes two country clusters. The first cluster shows an expanding trend, such as Czechia, Denmark, Luxembourg, Slovakia, Spain, and Sweden, and the second cluster indicates a diminishing trend, like Austria, Belgium, Bulgaria, Cyprus, Finland, France, Germany, Ireland, Italy, the Netherlands, Poland, and Slovenia.

The foreseen level of the industrial water withdrawal as percent of total water withdrawal for 2020–2050 foregrounds two country groups. The first group consists of Bulgaria, Cyprus, the Netherlands, and Slovenia which display an increase tendency, as opposed to the second group which indicates a fall tendency, for instance Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Poland, Slovakia, Spain, and Sweden.

The predicted value of the municipal water withdrawal as percent of total water withdrawal for 2020–2050 points out the a decreasing trend in states such as Czechia, Denmark, Finland, the Netherlands, Slovenia, and Spain, and an upward trend in states like Austria, Belgium, Bulgaria, Cyprus, France, Germany, Ireland, Italy, Luxembourg, Poland, Slovakia, and Sweden.

The limitation of the analysis consists in the relative heterogeneity of the source of data. Thus, the values of FAO's database come from the combination of three sources: (i) estimation either calculated as sum or resulted from official values or from AQUASTAT database estimation; (ii) official values; (iii) imputed (obtained by using methods such as linear interpolation, vertical imputation or last observation carry forward). Furthermore, in the case of Malta, only the total water withdrawal per capita could be analyzed because in the AQUASTAT database the value of the total water withdrawal per capita was higher than the total renewable water resources per capita which is an erroneous issue.

The conclusions are limited to the analyzed countries and cannot be extended to other EU, non-EU or world states. Therefore, future researchers could focus on other countries and new indicators from the water resources and water use categories.

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An Introduction to the Use of Life Cycle Assessment in Machining

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Abstract In today's globalized economy, growing concern exists regarding the tradeoff between economic growth and respect for the environment. This conflict is not alien to companies; as many have started to include environmental sustainability in addition to their usual objectives of profitability and efficiency. The manufacturing industry is a major contributor to the overexploitation of resources and to environmental pollution through the generation, accumulation or improper disposal of waste and greenhouse gas emissions. In this context, machining is one of the main processes in manufacturing. Its intrinsic characteristics make it an intensive process regarding energy, water consumption, and waste generation. In addition, cutting tools suffer from high wear rates that result in high tool consumption and, thus, a high environmental footprint. Life Cycle Assessment (LCA) is the most widely used methodology for assessing the environmental impacts of manufactured products. It has also been used in machining because it allows a holistic approach that encompasses all environmental exchanges of a product or process throughout its life cycle. Particularly, it allows comparing scenarios when a proper baseline is established to select more environmentally friendly ones. However, comparisons among setups that include, for instance, different workpiece materials are hardly helpful due to the influence of machinability on the process. The present study is aimed at introducing LCA into machining. It provides an overview of relevant studies in which the LCA framework was applied to machining and other manufacturing processes.

Keywords Energy · Raw materials · Life cycle assessment · LCA software · Machining · Sustainable manufacturing

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1 Introduction

In today's globalized economy, the conflict between economic growth and respect for the environment is becoming increasingly acute (Liu et al., 2018a). The levels of well-being achieved in developed countries have led to more significant social concern for environmental issues, which companies also have internalized. From the design of their products to their industrialization and distribution, companies modify their behaviors to comply with regulatory frameworks and to respond to consumers' new agile and "green" demands (Kaswan & Rathi, 2020; Ozcelik et al., 2021; Sartal et al., 2017).

Today, environmental sustainability is an imperative strategy for business organizations in this new context. It must be added to the usual profitability and efficiency objectives (Garza-Reyes, 2015; Sartal et al., 2017, 2022). The traditional assumption that natural resources are limitless and that the environment can compensate for all human actions is no longer acceptable (Garetti & Taisch, 2012). The rapid consumption of natural resources and the acknowledgment of human activity as the source of global warming have increasingly motivated firms to modify their strategies and develop cleaner manufacturing processes and services to be ecologically sustainable (Barreto et al., 2010). In light of this, the green paradigm has emerged. This philosophy aims to diminish or avoid all negative impacts of the firm's products and services on the environment. Moreover, it is linked to operations, with the objective being to improve environmental efficiency while also keeping the organization's traditional profitability goals intact (Garza-Reyes, 2015).

The manufacturing industry is of paramount importance within the industrial sector. According to the latest available data (2021), it is estimated that the manufacturing industry represents 17% of the gross domestic product (GDP) of national economies (World Bank, 2022) and 13.1% of world employment (ILOSTAT, 2020). As a result, manufacturing is the one of the major contributors to the overexploitation of resources (energy, raw materials and water), as well as to environmental pollution through the generation, accumulation or improper disposal of waste and greenhouse gas emissions (Álvarez et al., 2017; Goindi & Sarkar, 2017; Sun et al., 2019).

Many industries already evaluate their environmental footprint and have changed the guidelines of their production by considering strict norms and environmental regulations (Yıldırım et al., 2019). Therefore, the discussion on implementing sustainability strategies in manufacturing has become a trending research topic (Mia et al., 2019), with the objective being to increase the processes' efficiency while also increasing production rates (Gupta et al., 2016, 2020).

Machining is an essential manufacturing process (Aramcharoen & Mativenga, 2014; Pusavec & Kopac, 2009). Its intrinsic characteristics make it an intensive process with regard to energy and water consumption, as well as waste generation (Campatelli et al., 2014; Cao et al., 2012; Chen et al., 2015; Goindi & Sarkar, 2017; Wickramasinghe et al., 2020; Zhao et al., 2012). In addition, due to the severe conditions during material removal, cutting tools suffer from high wear rates that result in high tool consumption and, thus, high environmental costs.

All of the above mentioned circumstances show that machining processes generate relevant environmental impacts. Therefore, improving the sustainability of machining should be a clear objective for companies in their transitions from traditional production systems to sustainable ones. Various conventional sustainability assessment methods have been used, including mathematical modeling, life cycle assessment (LCA), empirical modeling, etc., to improve environmental performance. These methodologies allow for analyzing the results of a process in connection with environmental and machining aspects (Hegab et al., 2018a, 2018b; Mia et al., 2019; Singh et al., 2020).

The LCA methodology is the most widely used for analyzing the environmental impacts of manufactured products (García et al., 2014). Regarding machining, LCA is gaining attention as a method for evaluating a process's sustainability (Campitelli et al., 2019). This attention is probably given because LCA allows for a holistic approach that encompasses all of the environmental exchanges (emissions, energy, raw materials and waste) of a product or process throughout its life cycle (Campitelli et al., 2019; Filleti et al., 2017). In addition, it is a standardized technique (International Organization for Standardization, 2006a, 2006b), which may allow for comparisons between similar processes to select the most efficient use of resources and, therefore, the most environmentally friendly alternative.

In recent years, the use of LCA for assessing manufacturing processes has been implemented, and several related studies can be found in the literature. However, the need still exists for critical reviews that gather the developed knowledge and present to readers a comprehensive overview that shows the potential and limitations of the method.

Given the relevance that machining processes have in matters related to the environment, the present chapter focuses on the sustainability of the machining processes. Mainly aiming at developing a complete review of the recent work on LCA in machining and comparing it against other manufacturing processes. This review will allow readers to understand the current state and the challenges in the coming years. The chapter includes four sections after this introduction. Section 2 covers the main issues related to sustainability in machining. Section 3 briefly describes the LCA methodology. Section 4 discusses the application of LCA to machining and other alternative manufacturing processes. Section 5 presents some implications and insights. Finally, Section 6 summarizes the chapter's main conclusions.

2 Sustainability in Machining

Machining is one of the most extended manufacturing processes in the industry. It is a subtractive one, in which the final shape of a part is obtained by removing chips from a workpiece using sharp tools. Conventional machine tools, such as grinding, milling and turning machines, and modern flexible CNC centers are used to do the operations. The machine tools have evolved from traditional manual machines to

modern CNC machines that offer users high precision and flexibility for producing intricate shapes.

Machining is a complex process that is highly demanding in terms of energy requirements and includes various inputs, such as cutting tools and cutting fluids. Cutting tools can be either solid tools or indexable tools made of a wide range of materials, which require proper tool holders. Cutting fluids, which generally use animal, mineral or vegetable oils mixed with water and other chemical compounds, are usually employed. The process can be arranged in multiple ways, including fixture settings, machining parameters, operations order, path strategies, etc. Regarding the outputs, machining produces a large quantity of chips, cutting fluids to be reused or disposed of, dust generated during cutting and gases produced through the vaporization of the cutting fluids. In Fig. 1, one can see the main inputs and outputs in machining involving both traditional and non-traditional processes, particularly those relevant to the environmental impact.

Based on Fig. 1, two approaches are open for researchers to improve the sustainability of the process. One is to evaluate a specific input or output to diminish or suppress the associated environmental impact, such as reducing energy consumption and, thus, atmospheric emissions. The second is integrating all inputs and outputs to perform a single evaluation. This strategy combines all accessible and relevant process information to assess its impact by incorporating the effects of inputs and outputs. Some authors propose using algorithms that allow for conveniently integrating the data. For instance, Hegab et al. (2018a) presented metrics for evaluating a process's sustainability. Other approaches can also be identified, such as incorporating the environmental point of view into the design process, which is eco-design (Favi et al., 2019; Züst et al., 2016). Another method is the Life Cycle Assessment (LCA), which will be reviewed in more detail in the following sections. Finally, some researchers, such as Tao et al. (2018), have proposed more integrated approaches for

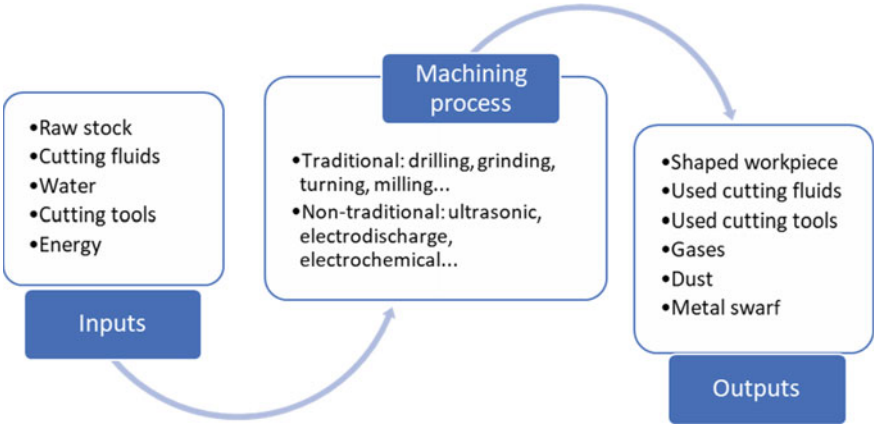

Fig. 1 Machining process: inputs and outputs

eco-design by integrating the modules of LCA, CAD/CAE and optimization to drive product design with a sustainable approach.

The inputs of the process can be differentiated into raw and intermediate materials, including the cutting fluids and water, workpiece materials, cutting tools, and energy (power consumption). The relevance of the inputs is clear by noting that most of the residues are generated directly from them, such as the cutting tools. Next, these sources are explained in more detail.

2.1 Raw Materials

Machining involves using raw materials, such as cutting tool and workpiece materials, as well as mineral or vegetable oils, which are usually mixed in water or gases. The influence of these materials on the environment should be conveniently analyzed. For a long-term analysis, even materials used for manufacturing the machine-tools should be considered input materials considering that they may be recovered, such as those used for structural uses (e.g., cast iron) (Cao et al., 2012).

The use of traditional cooling/refrigeration methods (i.e., flood cooling) based on mineral oils is identified as a harmful solution for human health and ecological systems (Wickramasinghe et al., 2020). Thus, in the last decades, efforts have been carried out to devise sustainable alternatives. These more recent strategies are helping to foster the development of greener processes and include, among others, dry machining, cryogenic machining and minimum quantity lubrication (Carou et al., 2016; Sarıkaya et al., 2016).

Benedicto et al. (2017) presented a comprehensive comparison of some of the main cooling/refrigeration alternatives based on their environmental impacts. They analyzed several dimensions: residue, fluid drag-out, dangerous substances, mist and emissions, and workers' health hazards. The methods were compared based on their relative costs and sustainability, with dry machining and gaseous cooling being the more sustainable solutions. In the review, dry machining was identified as the cheaper solution. However, despite the undoubted benefits of dry machining, it still finds problems for application when machining certain materials, for instance, due to the temperature increase in the cutting zone and tool (Goindi & Sarkar, 2017).

Water consumption is one of the major current concerns in terms of sustainability. Access to water is one of the Sustainable Development Goals of the United Nations (2022). The industry is one of the major consumers, and efforts are being made to reduce its water consumption. Zhao et al. (2012) presented a study on freshwater consumption in the drilling, milling and turning of medium carbon steel using the Unit Process Life Cycle Inventory (UPLCI) model. In the study, the direct water footprint is associated mainly with cutting fluid consumption and system maintenance. The indirect water footprint linked to energy consumption is related to electricity consumption. One of the major contributions of the study is the finding that the indirect water footprint is larger than the direct one is. Still, it notably depends on the data used for the estimation (i.e., a state of the country). Chen et al. (2015) also analyzed

the water footprint of the machine tools, identifying that the use stage dominates the water footprint.

Though other workpiece materials could be used in machining, metals such as aluminum, cast iron, steel and titanium are commonly used. Machining these materials is always demanding in terms of energy due to the associated heat and mechanical power requirements. Thus, the effects of workpiece materials should be evaluated. In this sense, Bonilla Hernández (2019) studied the influence of two materials on both energy consumption and CO_2 footprint. These two materials were: Ti-6Al-4V, a titanium alpha–beta-alloy in a solution-treated and aged condition, and MP159, a cobalt-base-super alloy, multiphase, in a solution-treated, cold-drawn and aged condition. The authors analyzed the material extraction, manufacturing, transport, use and end-of-life potential. The extraction of Ti-6Al-4V requires more energy and has a higher CO_2 footprint, while the contrary occurs for manufacture, transport and use. Moreover, the end-of-life potential (recycling) of Ti-6Al-4V is much higher than that of the MP159. Moreover, the machining requirements depend on the machinability of the material itself. For instance, the power required for machining depends on the material, as shown in Carou et al. (2015).

Cutting tools are made of a wide range of materials, such as high-speed steel, tungsten carbide, alumina, cubic boron nitride and polycrystalline diamond. In addition, a wide range of solutions are available for coating the substrate materials, for instance, titanium nitride, titanium carbo nitride and titanium aluminum nitride. Cutting tools and coatings requires large amounts of raw materials and energy. Thus, a conventional evaluation based on productivity must be accompanied by an ecological evaluation (Klocke et al., 2013). For instance, Li et al. (2017) studied the carbon emissions of coated inserts throughout their life cycle, identifying that 70–80% of these emissions were related to the usage phase.

Efforts are also being made in non-traditional machining processes to improve their sustainability by eliminating or reducing unsustainable raw materials. For instance, Dong et al. (2019) proposed an alternative material for removing kerosene from the electrical discharge machining (EDM) process by using a novel water in oil (W/O) nanoemulsion dielectric.

2.2 Energy

Machining involves a wide range of parameters that could affect a process's results in terms of the quality of the machined surfaces (Rubio et al., 2012), cutting tool wear and environmental impact. Moreover, different machining strategies may be employed to machine a specific part, affecting outcomes, such as power consumption. In this sense, Vila et al. (2015) studied various strategies in the milling of AISI D3 hardened steel by using a face mill with a 52 mm diameter and five carbide inserts featuring PVD AlCrN coatings. Mainly, the contour, one-way (X-axis), one-way (Y-axis), zigzag (X-axis) and zigzag (Y-axis) strategies were used. The authors related the power consumption to the CO_2 emissions, and the results showed how the milling

strategy played an essential role in the amount of CO_2 emissions. Specifically, the results for the X-axis resulted in a more sustainable solution. In contrast, the zigzag strategies were more demanding regarding power consumption, placing the contour strategy in the middle. The material removal rate was also found to be critical for CO_2 emissions, which in connection to the strategy may increase them close to 50% from the optimum solution. Aramcharoen and Mativenga (2014) also studied the influence of the toolpath on energy consumption in the milling of T316L stainless steel. Similarly, the strategy taken to mill a part was studied by Campatelli et al. (2014) by changing the orientation of the workpiece and evaluating the energy consumption.

Energy consumption in machining is mainly due to the cutting forces required to cut the workpiece material. Thus, it depends on the type of material to be cut (i.e., its machinability). Anyway, the cutting power can be diminished using the selection of an optimized cutting speed. Although energy is not precisely linked to atmospheric emissions due to its dependency on the geography/energy mix (Linke et al., 2012), it is a good indicator of a machining process's environmental impact. Many studies on energy in machining have been presented over the past several years. Some of them are conveniently reviewed by researchers such as Peng and Xu (2014) and Yingjie (2014).

A study by Cica et al. (2020) provides a good example of examining energy (power) usage during the machining of AISI 1045 steel. The authors employed three regression-based machine learning techniques: polynomial regression, support vector regression and Gaussian process regression. These techniques allowed for predicting machining force, cutting power and cutting pressure. They involved selecting as machining parameters the cutting speed, the depth of cut and the feed rate. Wang et al. (2019) evaluated a machining process for prismatic geometries using the STEP-NC standards. Yip and To (2020) presented a model to assess energy consumption, in which both the material removal and the material recovery were included. The model was assessed through an experimental investigation using diamond tools to machine Ti-6Al-4V. Bi and Wang (2012) presented a study on energy consumption with a modeling method based on the kinematic and dynamic behaviors of chosen machinetools. Models were also developed for analyzing non-conventional processes, such as electro-discharge machining (Li & Kara, 2015).

Jia et al. (2018) evaluated the energy consumption of the machine-operator system using a model that includes the energy consumption of the operator, which is not usually done in energy studies in machining. After presenting the model, the authors showed an example of the CK6153i CNC machine-operator system identifying potential energy savings of 15.85%.

As discussed above, carbon emissions are related to energy consumption. In this sense, Jeswiet and Kara (2008) proposed a model for calculating CO_2 emissions based on the electrical energy consumed to produce a component or manufactured product by using the Carbon Emission Signature (CES™) as calculated for the energy mix. The authors used the method for analyzing the turning of a titanium bar and an aluminum bar. They used the compressing of an aluminum billet for the electrical grids of Ontario (Canada) and New South Wales (Australia). Mulyadi et al. (2015) employed the CES™ method to assess the milling of H13 tool steel. Global

warming potential calculated from the cooling, tool change, cutting, ready, and setup energies clearly showed the influence of the used cooling environment. Mainly, dry and minimum quantity lubrication (MQL) conditions produced almost half of the emissions compared with the flood environment. Similar results were obtained when analyzing the acidification and human toxicity levels.

Machinetools, particularly old ones, can represent a source of higher energy consumption, as highlighted by Kianinejad et al. (2015). The authors identified that the specific energy consumption of the outdated milling machine was, on average, 40% higher than the newer one. Moreover, the configuration of the machinetool may affect energy consumption. In this sense, Harris et al. (2015) evaluated the influence of electric and pneumatic ultra-high-speed machines on energy consumption, highlighting that a turbine spindle consumes a considerably higher amount of power than an equivalently rated electric spindle tool does.

3 Life Cycle Assessment

The first initiatives to analyze the life cycle of materials and products can be traced back to the late 1960s and early 1970s (European Environment Agency, 1997). Notably, the Coca-Cola company conducted an LCA in 1969 (Hunt et al., 1996). LCA is a methodology or a "way of thinking" (Clark & de Leeuw, 1999). It aims at evaluating, in the most objective way possible, "the environmental loads associated with a product, process, or activity, identifying and quantifying the use of mass and energy as well as the emissions to the environment" to identify the environmental impact (Carvalho et al., 2011). The methodology uses several impact categories, such as climate change, resource depletion, ecotoxicity, etc. (European Comission, 2016). Mainly, a critical activity for developing LCA is accurately identifying and quantifying all input and output flows from the system (Ciroth el al., 2020; Ferrari et al., 2021).

Some authors identified LCA as a decision-support tool (Hertwich & Hammitt, 2001; Pryshlakivsky & Searcy, 2021). It is increasingly used as a management and product design tool (Malmqvist et al., 2011). This identification is essential when considering its main limitations. Companies can conduct LCAs to identify potential improvements in their manufacturing processes. LCA also can provide environmental data to the public or the government, identify best environmental practices and waste reduction options, and compare processes or products at multiple points during manufacture and use. Perhaps the most critical time for making decisions is during the design stages of new products. According to Rebitzer (2002), the generation of environmental impacts mainly occurs in the latter phases of the product's life cycle (i.e., end of life). Still, it must be considered that the environmental impacts are primarily determined during the design/development phase.

3.1 Methodology

LCA collects all inputs and outputs during the material flow process at every production step. The methodology is aimed at calculating the environmental impacts following four main steps, namely (International Organization for Standardization, 2006a, 2006b):

(i) Goal and scope definition, where the aim is described and the boundaries are fixed.
(ii) Life Cycle Inventory (LCI), where all the data related to the raw materials and energy corresponding to the studied system are collected. The inputs and outputs are assembled during the analysis at each manufacturing process step. LCI is the phase in which each environmental aspect of a system is compiled and quantified. Ferrari et al. (2021) stated that "the LCI is the most delicate and challenging phase."
(iii) Life cycle impact evaluation, where output emissions and input resources are clustered into impact groups and transformed into the same units for comparative assessment.
(iv) The interpretation of the LCI and effect evaluation.

Since the concept of Life Cycle Analysis appeared, numerous tools have been developed to facilitate the computation. Most available programs include databases, while others allow importing free and commercial databases to work with. The European Commission, Methodology Study Eco-Design of Energy-Using Products (MEEUP) classifies LCA studies according to computer tools, methodologies and databases.

Commercial software is available for properly conducting LCA. It should be noted that LCA software is generic and can be used for any industrial area. The tool's power and reliability rely on the database. Specific databases exist for chemical products, eco-design, industrial products and packaging. Some even allow users to associate costs and perform economic analysis. Tools exist for conducting LCA studies for virtually all specific products and sectors. Thus, they must be selected depending on the objective and scope established. Therefore, databases exist for different industries (plastics, food, construction, clothing, chemicals, etc.). Kalverkamp et al. (2020) identified some of the most used databases, for instance, ecoinvent, GaBi professional, Probas, the U.S. Life Cycle Inventory (USLCI) Database, the International reference Life Cycle Database (ILCD) and the Global LCA Data Access network (GLAD).

LCA must be considered a decision support tool. However, it should reflect on the tool's limitations. For instance, when attempting to conduct LCA, it should be considered that the type of information is merely an indicator. LCA should not be misunderstood as a complete assessment; it extensively uses subjective judgment, and the lack of scientific or technical data is sometimes apparent (European Environment Agency, 1997). For instance, De Rosa et al. (2018) indicated that methodological choices might have a significant effect on the LCA outcomes. Other researchers, such as Hélias and Servien (2021), claimed that the need still exists to advance in using the same data sources and normalization references.

3.2 LCA of MachineTools

Machinetools are complex systems composed of mechanical, electrical and fluid-powered devices (Zendoia et al., 2014). The objective of a machine tool is to allow for the manufacturing of parts according to the dimensional and geometrical requirements (Duflou et al., 2012). Machine tools should have high stiffness and damping capacity, which is generally guaranteed by heavy structures (i.e., mainly cast iron; Marichelvam et al., 2021), to meet the requirements.

In general, the life cycle stages of machine tools used to calculate their environmental impacts are as follows (Cao et al., 2012; Hu et al., 2012):

- *Material production*: material extraction, processing, heat treatment, etc.
- *Use*: it is an energy-intensive stage due to the power needs for operating the machines (e.g., axis movements, tool changes, etc.) and the high cutting power consumed during operation. The environmental impact in this phase is the highest.
- *Transport*: it works as a bridge among the other life cycle stages.

By note of caution, it is essential to indicate that generally, the manufacturers of the machine tools, cutting tools, jigs, fixtures, etc. are not willing to release specific details. For instance, they consider that the types of materials, their weights, and their processing details are crucial and "proprietary" information. This lack of knowledge is one of the main inconveniences in developing completely reliable LCAs.

4 Life Cycle Assessment in Machining

4.1 Studies in Machining Processes

In Sect. 2, several strategies oriented toward sustainability in machining were identified. LCA is a suitable tool for machining processes because it considers the whole process, including all inputs/outputs. However, it could also be used to analyze a specific part of the process—for example, to evaluate the utilization phase of the machine tool (González, 2007). In the last years, researchers have paid increased attention to the application of LCA in machining as can be seen in Fig. 2. The graph shows an increasing number of results for "life cycle assessment" AND "machining" in the Scopus database using the "all fields" option.

The assessment presented in this chapter offers a big picture of the use of a machining methodology that allows actions to suppress or at least diminish the environmental impacts. Next, some experimental studies that employ the LCA approach in machining are reviewed and summarized in Table 1.

Gupta et al. (2020) analyzed the use of different turning conditions in the machining of pure titanium. The results were analyzed using SimaPro 8.3 using two databases: EPS 2000 and ReCiPe Endpoint v1.12. Both methods offer similar

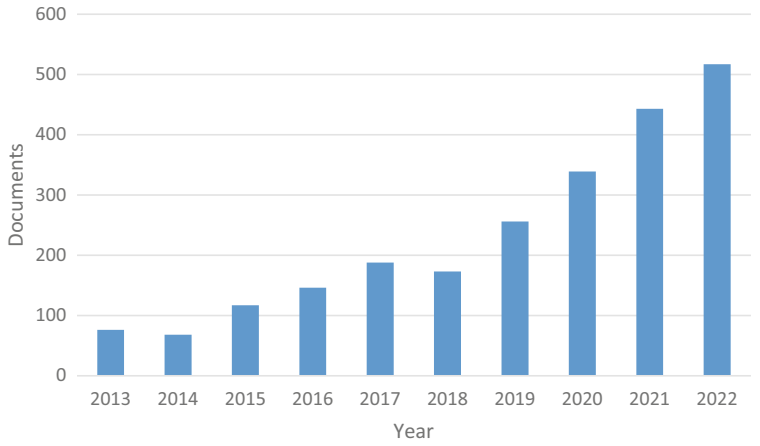

Fig. 2 Documents in Scopus database for "life cycle assessment" and machining between 2013 and 2022 according to Scopus on February 13, 2023

results. Based on their study, the authors stated that the most significant impacts depend on energy consumption.

Mia et al. (2019) conducted an experimental study on the turning of the Ti-6Al-4V alloy. The experimental tests included dry machining and cryogenic machining (mono and dual jet) using liquid nitrogen tests. The LCA was carried out with SimaPro 8.3 using two databases: EPS 2000 and ReCiPe Endpoint v1.12. The results showed that dry machining requires higher cutting forces than the cryogenic alternative. Thus, the experimental tests with the higher environmental impact are those in which dry machining conditions were used.

Campitelli et al. (2019) studied the drilling and milling of aluminum alloy, cast iron and steel. The software used for carrying out the LCA was the LCA 1.4.2. The database was the ecoinvent 3.1. The CML 2001 method was used, and one of the main results included the recognition of flood cooling as the most important reason for increasing the environmental impact. The higher effect was due to an increase in energy consumption due to pumping and fluid consumption against the minimum quantity lubrication system. Furthermore, flood cooling generates hazardous waste. The major impacts of cutting fluids are associated with land use and terrestrial ecotoxicity. The researchers highlighted electricity, compressed air and flood lubrication oil as key factors for improving the process's environmental efficiency.

Filleti et al. (2017) evaluated using CBN and Al_2O_3 grinding wheels on the machining of Inconel 751. The study was performed using GABI software, and the UPLCI methodology allowed for identifying energy as the main contributor to the impact categories studied. Besides, it was possible to find that the material removal rate greatly influenced the results. Moreover, some subunits (e.g., hydraulic, cooling,

Table 1 Summary of experimental studies in machining using LCA

Author	Software/methodology	Methods	Machining process/workpiece material/tool material/cutting environment	Environmental impact
Gupta et al. (2020)	Simapro 8.3	EPS 2000 ReCiPe Endpoint v1.12	Turning Pure titanium Uncoated carbide MQL and Ranque-Hilsch Vortex Tube assisted Minimum Quantity Cutting Fluids	Human health, ecosystem production capacity, abiotic stock resource, biodiversity Human health, ecosystems, resources
Mia et al. (2019)	Simapro 8.3	EPS 2000 ReCiPe Endpoint v1.12	Turning Ti-6Al-4V Multi-layered TiCN/Al_2O_3/TiN coatedWC Dry, and mono and dual-jet cryogenic cooling	Human health, ecosystem production capacity, abiotic stock resource, biodiversity Human health, ecosystems, resources
Campitelli et al. (2019)	Open LCA 1.4.2	Ecoinvent v3.1	Drilling and milling Aluminum, cast iron and steel Solid-carbide and hard metal MQL and flood	Fourteen impact categories from CML 2001
Filleti et al. (2017)	GaBi 6—UPLCI	GaBi	Grinding Inconel 751 alloy Al_2O_3 (JB126 K150 VSS) and CBN (8B126 K150 VT2) Flood	Global warming potential, Ozone layer depletion potential, Acidification potential, Photochemical oxidation potential, Nutrient enrichment potential, Chronic water ecotoxicity potential, Acute water ecotoxicity potential, Chronic soil ecotoxicity potential, human toxicity potential via soil, human toxicity potential via water, human toxicity potential via air

(continued)

Table 1 (continued)

Author	Software/methodology	Methods	Machining process/workpiece material/tool material/cutting environment	Environmental impact
Damir et al. (2018)	Not available	Eco-indicator 99	Turning Ti-6Al-4V CNGP 120408 Sandvik, CVD coating Cryogenic and flood	Single score indicator
Gamage et al. (2016)	SimaPro 8	Ecoinvent v3.0 ReCiPe Endpoint (H) V1.11/Europe ReCiPe H/A Single score method	Electrical discharge machining: die sinking and wire Aluminum (3003) Copper and Brass Water	Machining wastes in solid, liquid, gas and aerosol
Liu et al. (2018b)	Not available	Eco-indicator 99	Milling Inconel 718 Tungsten carbide, (Ti,Al)N/TiN coating SECO XOEX 120408R-M07 F40M Dry and flood	Impact measured in milli-point (mPt)
Zanuto et al. (2019)	GaBi 6	Ecoinvent	Milling AISI P20 steel TiN-coated carbide and uncoated high-speed steel Lubricating oil (organic)	Abiotic depletion potential, Abiotic depletion potential, Acidification potential, Eutrophication potential, Freshwater aquatic ecotoxicity potential, Global warming potential, human toxicity potential, Marine aquatic ecotoxicity potential, Ozone layer depletion potential, Photochemical ozone creation potential, Terrestrial ecotoxicity potential

(continued)

Table 1 (continued)

Author	Software/methodology	Methods	Machining process/workpiece material/tool material/cutting environment	Environmental impact
Shi et al. (2021)	Not available	CLCD database	Turning Low-carbon alloy steel Steel Flood (water–oil)	Massive consumption of primary resources and generation of massive amounts of greenhouse gases
Shah et al. (2021)	Ecochain Mobius	ReCiPe 2016 midpoint (H)	Drilling Inconel 718 Coated solid carbide Liquid carbon dioxide and liquid nitrogen	Impacts on the environment, human health, and depletion of natural resources

cutting fluid pumping and exhaustion) may be optimized to notably reduce the environmental impacts, considering that they explain 45 to 70% of the electric energy consumption.

Damir et al. (2018) evaluated the influence of cryogenic and flood cooling in the turning of Ti-6Al-4V. LCA was carried out based on the Eco Indicator 99 method. As process inputs for flood cooling, it was considered to involve flood oil production, transport, machining and pumping. Meanwhile, as inputs for the cryogenic method, it was supposed to involve LiN production and transport, as well as Ni liquefaction and machining. The single indicator used as the output showed how the cryogenic method has a lower score than the flood method. The only positive activity of flood cooling is the recycled lubricant. Thus, the possibility of recycling the lubricant improves the total single score indicator. Sill, in any case, the total value is higher than that of cryogenic cooling, mainly due to lubricant production.

Gamage et al. (2016) evaluated electrical discharge machining with SimaPro software to evaluate energy consumption, tooling, cutting fluid and compressed air. The authors found that electricity was the major contributor to the environmental impact, representing 57 and 60% for die sinking and wire EDM, respectively. After that, in die sinking, dielectric oil accounted for 27% of the environmental impact, whereas 38% was due to the tooling (brass) in the wire EDM.

Liu et al. (2018b) used the Eco-Indicator 99 to assess the environmental impact of the milling of Inconel 718. Two cooling conditions were used: dry and flood. The authors discovered that the contribution of the workpiece material was high, from 30 to 50%, and that as the milling conditions increased, the contribution of the cutting tool consumption notably increased while diminishing the impact associated with energy consumption.

Zanuto et al. (2019) studied various strategies in the milling of AISI P20 steel. Gabi software was used to carry out the analysis. When referring to the inputs, the authors identified high deviations in the data provided through the software, leading to a high uncertainty level. Specifically, according to the software inventory, the amounts of the analyzed resources for milling 1.0 kg of low-alloy steel were given with a standard deviation from 105 to 332%. Some findings included the identification of slow speeds as a cause of more considerable environmental impacts. Thus, high-speed steels lead to more significant impacts than carbide tools do due to their slower speed requirements.

Shi et al. (2021) conducted a case study on the turning of low-carbon alloy steel parts. Using the LCA methodology, and per ISO 14955-1 (International Organization for Standardization, 2017), the authors analyzed the inventory data for energy and material consumption, as well as waste emissions, evaluating them for five categories of environmental impact. Their results showed that PED (primary energy demand), which includes three non-renewable sources of energy, and GWP (global warming potential) are the categories that offer the most significant environmental impact in this type of process. They further suggest that its environmental performance could be improved by increasing the cutting efficiency and using low-environmental load materials for the turning unit.

Shah et al. (2021) analyzed the drilling of an IN718 plate with solid carbide drills by using two cryogenic environments: liquid carbon dioxide (LCO2) and liquid nitrogen (LN2). They used tool wear, energy consumption and surface roughness as parameters. The study considered three cutting speeds, and the authors found that LCO2 increased drilling efficiency (between 25 and 300%). In addition, LCO2 reduced the pushing force by 14%, energy consumption by 19% and surface roughness by 11%. However, the LCA analysis showed that LN2 had a lower ecological impact in 17 of the 18 categories analyzed.

4.2 Studies on Machining and Alternative Processes

LCA can also be used as a comparative tool for assessing the suitability of a specific manufacturing process against others depending on the environmental impact. However, in this case, the complexity increases as more data are required to adequately model the processes, using very different machines based on other operating principles. Thus, the materials used and the energy needed to operate can vastly vary. Moreover, in most cases, data are unavailable and should be estimated. Some of the major scientific studies are briefly reviewed and summarized in Table 2.

Ingarao et al. (2018) compared additive manufacturing (selective laser melting), forming and machining (turning) using LCA. Parts were made of high-strength AA-7075 T6 aluminum alloy. The Ecopoint was the selected impact metric by the authors. The impact categories were calculated by applying the ReCiPe method H/A, an update of the Eco-Indicator 99 and CML 2002 methods. Different geometries were evaluated, and even for the most suitable geometry for additive manufacturing, it was found that the environmental impact of additive manufacturing was higher than that of conventional machining due to the high-energy intensity of processing for additive manufacturing. The weight reduction provided through additive manufacturing helps

Table 2 Summary of the main processes versus machining using LCA

Author	Machining process	Alternative process
Ingarao et al. (2018)	Turning	Additive manufacturing (selective laser melting) and forming
Serres et al. (2011)	Conventional machining	*Construction Laser Additive Directe*, in French (CLAD)
Deboer et al. (2021)	Machining	Casting (forming), and three additive manufacturing methods (binder jetting, powder bed fusion and bound powder extrusion)
Bekker and Verlinden (2018)	CNC milling	Wire arc additive manufacturing, green sand casting
Zendoia et al. (2014)	Milling, drilling and boring	Abrasive water jet machining
Jiang et al. (2019)	Grinding and milling	Laser engineered net shaping

to reduce transport impacts but still does not compensate for energy requirements for manufacturing.

Serres et al. (2011) compared the direct additive laser manufacturing (CLAD) approach with the conventional machining of Ti-6Al-4V. Additive manufacturing proved to be a more sustainable solution using LCA (Ecoscore from Eco-Indicator 99 methodology) mainly due to the high mass of chips in machining, which could reach up to 80% of the total consumption.

Deboer et al. (2021) carried out a comparative study through the LCA of various categories of manufacturing processes: casting (forming), machining (subtractive) and three additive manufacturing methods (binder jetting, powder bed fusion and bound powder extrusion). Using three environmental metrics (water consumption, energy requirements and CO_2 emissions), the authors evaluated the life cycle of a double cardan H-yoke. Their findings showed that forming is the most environmentally friendly process for large-scale production. Among additive manufacturing technologies, powder bed fusion combined with renewable energy was the most environmentally friendly option, reducing CO_2 emissions by 9.2% compared to casting. Finally, they found that machining has the worst performance from an environmental perspective due to the amount of waste material.

Bekker and Verlinden (2018) compared the environmental impacts of wire arc additive manufacturing, green sand casting and CNC milling of 308L stainless steel based on data taken from ecoinvent 3. ReCiPe endpoint totals showed that the material contribution was dominant. Therefore, additive manufacturing outperforms CNC milling when the material use increases because of the ability of additive manufacturing to decrease the weight of the part due to topology optimization.

Zendoia et al. (2014) presented a comparative study of abrasive water jet machining versus a set of conventional operations (milling, drilling and boring) for one aeronautical part, using SimaPro7 Analyst based on the ecoinvent database. The authors stated that further work is still required to evaluate the alternative route to justify the substitution when dealing with larger batch sizes.

Jiang et al. (2019) compared CNC machining (grinding and milling) and the laser engineered net shaping (LENS) process to manufacture gears of AISI 4140 steel. The authors used the GABI software, identifying that the LENS process is more sustainable than the CNC machining.

5 Implications and Insights

5.1 The Importance of Machinability

In Sect. 4.1, a review of recent studies on using LCA in machining was presented. No comparisons were made between these studies. One reason for this is that different processes were included (turning, milling, grinding, etc.) that have essential differences in terms of issues, such as the material removal rate. Moreover, the nature

and elements of traditional mechanical machining processes are different from those of non-traditional processes, such as the electrical discharge machining process, a thermal-based method.

A key issue to consider is the machinability of the materials. It is well known that the different machinability of the materials demands other machining conditions. In this sense, materials such as aluminum, nickel-based and titanium alloys, and steels require different amounts of cutting power to be machined (Polmear, 2005; Carou et al., 2015). Conventionally, cutting power is approximated using Eq. 1, thus depending on the cutting force (F_c) and the cutting speed (v) (Khan et al., 2020).

$$P_c = F_c \times v \tag{1}$$

By way of example, research on the conventional turning of Ti-6Al-4V alloy in semi-finishing conditions requires cutting speeds from 40 to 100 m/min (Lindvall et al., 2021). Difficult-to-cut materials are "easier" to cut by using low cutting speeds. In this sense, the cutting speed ranges for materials such as nickel superalloys are like those of titanium alloys. For instance, Thrinadh et al. (2020) turned Inconel 718 using cutting speeds from 65 to 85 m/min. However, when it comes to materials with better machinability, the cutting speed can be immensely increased. For instance, Abas et al. (2020) used cutting speeds from 400 to 700 m/min to turn the 6026-T9 aluminum alloy.

The machinability of various materials drives researchers and practitioners to select different cutting tool materials among those available. They may also have to use cutting fluids or suitable alternatives. Uncoated cemented carbides are conventionally used for titanium alloys (Lindvall et al., 2021), while coatings such as TiB_2, TiC, TiN, and Al_2O_3 are improving the machining of aluminum alloys (Rao & Gopal, 2021). The influence of the processing of the cutting tool material on the environmental impact is critical. Moreover, tool wear plays a crucial role in the process due to its effect on productivity (i.e., number of inserts, tool changes, etc.). Most of the LCA research does not include a detailed evaluation of the impact of tool wear. In this regard, the study by Kim et al. (2021) is worth noting. The authors presented a detailed study on tool wear for both ceramic and CBN inserts using cryogenic, dry and wet machining, relating CO_2 emissions to the tool life under the analyzed machining conditions.

5.2 Energy Evaluation

Energy consumption is a critical input for LCA. Commercial software can be used to estimate energy consumption in machining, but it may be underestimated, as He et al. (2022) pointed out. In machining, cutting and non-cutting times coexist. Thus, Eq. 1 allows for the accounting of only a part of the total energy consumption. In this sense, it should be considered the demands for the spindle, axes motion, cutting resistance (workpiece materials, cutting tool and cutting conditions) and others (cutting fluid

pump, cooling device, computer controller) (Aramcharoen & Mativenga, 2014). The number and complexity of the tasks involved in machining make it challenging to estimate energy consumption with accuracy.

To understand and estimate energy consumption, researchers have developed energy consumption models. Aramcharoen and Mativenga (2014) critically reviewed eight models developed from 2006 to 2013. According to the authors, one of the major drawbacks of the existing models is that they do not fully capture the complexity of the machining process, and some tasks that consume energy are not included. The development of fully comprehensive models for energy consumption is a requirement for the LCA because omissions may compromise the results.

When energy consumption is divided into several tasks, the results of the LCA can be more helpful, as they can help to identify the contribution of different sources of environmental impacts. For instance, this is clear when attending to the cutting environment. The type of raw material used as environment influences the impacts and the energy required for the cooling/refrigeration system. Some models do not include the proper assessment of the energy that the cutting fluid system or alternatives consume (Mulyadi et al., 2015).

In addition, the same machining operation can be performed using different strategies. It should be noted that a large amount of energy, up to 30%, is consumed in non-cutting operations (e.g., tool path, tool change and change of spindle rotation speed; Hu et al., 2017). Because of this, LCA must be carried out by approaching the analysis of energy consumption "line by line" through the CNC code, as using only cutting operations or uncomprehensive analysis results in improper assessments.

5.3 Applicability

Comparisons among different experimental studies are difficult to make when the workpiece material, cutting parameters, tools and machine tool are different (Zanuto et al., 2019). Specifically, these studies are not standardized, and the analysis largely depends on the authors' knowledge and juice.

In recent years, the number of experimental studies on LCA in machining has increased. However, the software/methodologies and methods, the processes analyzed, the tool and workpiece materials, and the cutting environments are not uniform, as shown in Table 1. The same applies to comparative studies among the manufacturing processes listed in Table 2. However, some insights can be obtained from the previous examples:

- First, the LCA methodology allows researchers and practitioners to evaluate the influence of their machining strategies on the environment. In this sense, evaluating the impact, by comparison, is reasonably straightforward when they have a suitable LCA methodology. It is true that, in some cases, it requires effort to create accurate inventories. For instance, it may require performing experiments to quantify inputs, such as energy consumption accurately, or to develop detailed

models for this. However, in the end, LCA may help determine the influence of alternative cutting environments, cutting tools or cutting parameters.

- Second, the influence of the factors is complex. No single factor always causes a major increase in the environmental impact of machining. In this regard, the studies allowed readers to identify how critical the cooling/refrigeration system is in some instances, whereas electricity is essential to others. By way of caution, it is important to note that the baseline for comparison in all cases is not the same. In other words, no "worst case" scenario exists for comparisons. This issue is evident when one is attending to the cooling/system. Thus, some use conventional/flood cooling, which can be deemed the "worst case" scenario, but others use more sustainable alternatives, such as MQL or cryogenic machining. In this sense, the importance of the cooling/lubricating system in terms of sustainability may be blurred. However, it needs to detail all the inputs related to the cutting environment, particularly those related to energy consumption.
- Third, the comparison increases its difficulty when it is made between two or more processes. Thus, researchers need to generate an inventory for each of the processes. The power of these studies relies on the fact that the variations in the effects may be more significant. In any case, process substitution can hardly be decided solely based on the environmental impact. The evaluations must consider aspects such as the productivity of the process, the quality of the resulting parts and the investment.

6 Conclusions and Future Work

Sustainability has gained relevance in the last decades. Manufacturing is one of the main contributors to environmental issues, such as energy consumption, environmentally damaging cooling/refrigeration strategies or the intensive use of raw materials. Thus, manufacturing is one of the targets for implementing sustainable practices. Life Cycle Assessment has been identified as one of the most promising initiatives.

Nowadays, machining is still one of the most important manufacturing processes for industry. Machining is a process in which raw materials and energy consumption is critical. Its widespread adoption has encouraged companies to adopt "green" practices. As a result, this chapter presents an introduction to the use of LCA in machining. In the review, it is possible to identify several studies using different software and methodologies to evaluate machining's impact on the environment. Moreover, it is possible to highlight studies in which machining is compared with other manufacturing processes.

These LCA studies can be considered the first stones that may lead to a more profound knowledge about the industrial operations' impacts on the environment. LCA has already proved to be a suitable methodology for comparisons, mainly varying operating conditions among several. For instance, this can be helpful when fixing critical factors such as the workpiece material because of the influence of machinability on the settings, as discussed.

Detailed, complete and reliable LCAs in machining are still far from being obtained, mainly due to the complexity of the machining process. Particularly, this is due to the absence of data regarding the materials used to produce machine tools and cutting tools (i.e., materials and weights), and the details of the processing of these materials. Thus, knowing the exact amount of materials, energy, and water required to produce a machine tool remains an "educated guess". In this sense, LCAs are simplified when focusing on operating conditions. Issues such as energy consumption are also complex to address and demand great effort from researchers. In the years to come, machine tool manufacturers will likely produce machines with advanced capabilities in terms of the electrical consumption analysis linked to the sensorization wave drive by Industry 4.0, which could help in accurately evaluating environmental impacts.

In the future, it would be helpful that all commercial materials, tools and machine tools would be accompanied by full certificates in which complete details regarding inputs would be indicated. In this sense, full traceability may be possible, representing a massive driver for the LCA methodology, not only for machining but also for a wide range of activities. Thus, voluntary initiatives, such as the European Ecolabel,[1] may serve as a base for providing LCA practitioners with improved data for conducting their analyses.

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Corporate Social Responsibility and Environmental Performance: Reporting Initiatives of Oil and Gas Companies in Central and Eastern Europe

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Abstract The need to promote sustainable development generates a paradigm shift in the business world. The business strategies of the companies are reconfigured, the environment, social and governance issues being observed so that the interests of the stakeholders are promoted and not only the maximization of profit for the shareholders is pursued. Large corporations are the promoters of complex social responsibility programs and are increasingly concerned with reporting their environmental and social performances that are followed by stakeholders. Thus, on the capital market, portfolio investors do not make decisions exclusively based on financial performance, but also consider the social and environmental involvement of the issuers. In the corporate landscape, oil and gas companies stand out both for the negative externalities they generate, especially for the environment, but also for their efforts to improve non-financial performance. This chapter analyses the non-financial behaviour of oil and gas companies in Central and Eastern Europe. The chosen research method was the content analysis of the sustainability, CSR or non-financial performance reports as well as the content of the companies' websites that have different sections such as "Sustainable Development", "CSR". The results of the study demonstrate the increasing involvement of these companies in promoting the principles of sustainable development and the increase of their concerns regarding

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the attitude of stakeholders and the reporting of results regarding non-financial performance.

Keywords Corporate Social Responsibility · Environment · Performance · Reporting · Oil · Gas

1 Introduction

Corporate social responsibility in relation with the environmental performance have been key issues on business approach for addressing the proper tools for their activities, especially in the companies from the oil and gas sector that are seen as the pioneers in supporting the CSR development (Frynas, 2009). With the expectations being increased with regard to the endorsement of CSR (Lee, 2008; Panait et al., 2022a, 2022b; Taneja et al., 2011), it is important to know the capacities of businesses to do so. Meanwhile there are plenty of studies doing that, in this work we are more interested to know about the reporting incentives of these companies, on the issues reported, the way they report and the frequency. As EU moves forward in the 8th Environment Action Programme entered into force on 2022, to be agreed for the common agenda for the environmental policy until 2030, it sets out priority objectives and the conditions needed to achieve the ambitious goals. As a further step ahead compared with the European Green Deal, this action aimed "to speed up the transition to a climate-neutral, resource-efficient economy, recognising that human wellbeing and prosperity depend on healthy ecosystems" (EC, 2022).

Based on the vision 2030, the role of companies and firms in community development becomes more and more crucial, given that the six priority objectives are connected with the companies' involvement and their strategies toward environmental issues and their role on the corporate social responsibility. If we consider companies as main micro-level actors of the society, and as they have to endorse ethical behaviours, to have contribution to sustainable development, to enhance the employees well-being and the welfare of society, as well as meeting the expectations of the stakeholders, it is quite evident that the corporate social responsibility (CSR) has become nowadays increasingly important and indispensable for any organization's success, corporate image and reputation (Freeman and Reed, 1983; Su et al. 2016; Hasan and Habib 2017; Kirat, 2015).

As the management guru Peter Drucker said: "What gets planned gets done", the management bodies need to plan strategies that get everyone in the organization headed in the right direction at the right time, and that ensure that resources are mobilized where required (McElhaney, 2009; Popescu et al., 2022). In this regard, Cycyota et al. (2016) in their study have reviewed publicly available documents of *Fortune*'s 100 Best Companies to Work For, and they have found that many highly regarded companies specifically link employee volunteerism toward CRS to their corporate social responsibility strategy. Kirat (2015) associates the success of a company with the CSR values endorsed by these companies and the integration of CRS vision in

their programs and activities. This study analyses the current status quo of corporate social responsibility and environmental performance reporting initiatives of oil and gas companies in Central and Eastern Europe, as it relates to firms from the oil and gas from the basket of the CECE oil and gas index launched by Vienna stock exchange. The paper considers the following two research questions:

RQ1: What are the main issues reported from the companies of oil and gas from the basket of the CECE oil and gas index?
RQ2: In what ways are these companies reporting?

Since the CSR has been the focus of companies for the last decades, the expectations about the responsible role of companies have been increasing as well, by often leading companies to introduce new strategies, techniques and tactics to integrate as best as possible the CSR practices and activities. Finally, this chapter is structured as following. The introduction includes the research questions and the contributions of this chapter. Next, a comprehensive literature review takes place, listing CSR and reporting initiatives, environmental reporting initiatives and indexes, theories behind CSR reporting, environmental performance of oil and gas companies, and environmental performance of non-oil and gas companies. Moreover, the study continuous with two important sessions, that of data and methods, and the research results. These steps allow a description of the current status quo in reporting by firms from the oil and gas industries from the basket of the CECE oil and gas index. As a result, the work addresses the discussions and conclusions, which serve as an overview of the current reporting practices of oil and gas companies to be used as detailed information of the derived and specific shortcomings.

2 Literature Review

2.1 CSR and Reporting Initiatives

Increasing ecological crises such as climate change, environmental pollution, resource depletion, and wildlife devastation lead to policy focus on sustainability. Accordingly, corporations are more and more engaged in mitigating the negative effects of their operations by measuring and reducing risks. Furthermore, the energy issue is gaining attention from academics and governments as the demand for green, renewable, sustainable energy sources has been growing, and its further increase is expected in the future (Chong et al., 2022). The United Nations Sustainable Development Goals (SDGs), while focusing on solving the challenges that contemporary society has faced, involves SDG 7 which aims to improve energy sustainability (Madurai Elavarasan et al., 2022). Energy security, accessible, affordable, and clean energy can prevent and mitigate energy poverty and improve societal wellbeing (Neacsa et al., 2020) as energy plays an essential role in sustainable economic growth (Andrei et al., 2017; Jiang et al., 2022). Consequently, energy companies need to

undergo the transformation and integrate clean energy objectives into their strategy that resonates with three pillars of sustainability: people, profit and the planet. Prior studies confirm that energy companies have implemented corporate social responsibility (CSR) programs to preserve the ecosystem, avoid pollution, and use more renewable energy sources (El-Mallah et al., 2019; Weder et al., 2019). Therefore, energy companies intend to contribute to the transition to a green economy through CSR initiatives and sustainability activities. They try to mitigate the negative effects of their production process, which is reflected in their sustainability reports (Puime et al., 2022).

Corporate social responsibility intentionally integrates environmental, social, and economic issues into the business strategy (Sánchez-Infante Hernández et al., 2020). The energy sector undergoes risks related to the environment, health, safety, as well as reputation, which can be addressed through CSR and simultaneously fulfil the expectations of public and civil organizations (Stjepcevic & Siksnelyte, 2017). CSR impacts companies' reputation, and brand image and causes cost reduction, which improves their financial performance and competitiveness (Porter & Kramer, 2019). Research results confirm the positive relationship between financial performance and CSR (Albuquerque et al., 2019). In addition, uncertainties, unexpected changes, and challenges can be handled through CSR (Gigauri, 2021). Thus, energy companies have internal motivation to implement CSR such as strategy, risk prevention, environmental protection, branding, reporting, and disclosing information, and external motivation such as increasing competitiveness, legislation requirements, and stakeholder engagement (Latapí Agudelo et al., 2020).

Furthermore, CSR and environmental reports are important for investment decisions as it is considered to be linked to decreasing risks (Tzouvanas et al., 2020). In addition, energy companies prepare CSR and sustainability reports to meet the increasing pressure of stakeholders (Karaman et al., 2021; Latapí et al., 2021). The expectations and pressure from stakeholders to companies' CSR reports have been enhanced and hence, voluntary disclosure of the information is no more sufficient but they have to comply with reporting standards according to specific industry indicators (Hillman and Dalziel, 2003; Hahn and Kühnen, 2013; Lestari et al., 2018). Moreover, many countries oblige corporations to disclose environmental information (Liu et al., 2022). For example, many energy companies disclose environmental information in their sustainability reports as it is required by the European directive reports (Puime et al., 2022). However, the studies demonstrate that when companies disclose environmental information willingly, this positively correlates with their environmental performance, and on the contrary, if such information is disclosed due to the requirements there is a negative correlation between the two—environmental disclosure and the actual environmental performance (Liu et al., 2022). Prior studies suggested that productivity decreases when environmental regulations are tightened (Albrizio et al., 2017). Wang and Zhang (2019) found that green production performance is not improved by environmental policies. Studies argue that companies that highly pollute the environment react more sensitively to ecological regulations than those with less polluting impacts (Lanoie et al., 2008). Scholars investigated oil and gas companies in Canada after the country has withdrawn from the Kyoto Protocol

and found that loosened environmental policy improved the investment efficiency of those companies because emission reduction pressure has been reduced (Dong et al., 2020). However, the study in Russia has shown that removing environmental requirements and loosening regulations did not increase foreign investments, and did not cause economic development (Shvarts et al., 2016).

The literature maintains that there is a positive relationship between sustainable performance and reporting initiatives of energy companies (Karaman et al., 2021; Manta et al., 2022; Rezaee & Tuo, 2017). Consequently, corporations are striving to include SDGs in their reports (Di Vaio & Varriale, 2020).Sustainable reporting (SR) includes economic, social, and ecological indicators and contributes to corporate development (Lozano & Huisingh, 2011). In this regard, Global Reporting Initiative (GRI) has become the prevalent SR practice globally (Fonseca et al., 2014; Kuzey & Uyar, 2017) to report companies' economic, environmental, and social implications. GRI as an independent international organization offers standards for sustainable reporting that are the most widely adopted (GRI, 2021).

2.2 Environmental Reporting Initiatives and Indexes

For several decades, the growing concern of stakeholders about the impacts of business operations on the wellness of the people, society and the natural environment are painstakingly being scrutinized by corporate stakeholders, hence compliance with standards and reporting of compliance in the form of sustainability reporting and environmental reporting have become a frontburner issue (Searcy et al., 2016). Also, corporate organisations are embracing 'the green' issues proactively by producing environmental reports voluntarily to provide information to stakeholders on the environmental consequences of their operational activities in the host communities and countries (Azzone et al., 1996). More importantly, environmental reporting is important in the global oil and gas industry because it could help mitigate environmental degradation, pollution and other ecological abuses of these companies developing countries where compliance and disclosures are less stringent (Alazzani & Wan-Hussin, 2013). The Sustainability Reporting Guidelines developed, popularised and issued in 2006 by the Global Reporting Initiative (GRI) is the most widely-used and reported in the literature on sustainability/environmental reporting. With regards to utility, scholars noted that sustainability reporting and environmental reporting are useful for corporate stakeholders, such as the general public, customers, employees, and investors and regulators/government agencies who expect companies to consider the broad social and environmental implications of their operational activities (Poplawska et al., 2015; Searcy et al., 2016).

There are several environmental reporting indexes in the sustainability reporting literature for measuring, evaluating and reporting the economic performance (impact on profit), environmental performance (impact on people), and social performance (impact on planet) of business organisations. Gholami (2011) explained that researchers and global rating agencies have consistently an environmental impact

assessment (EIA) for measuring corporations' 'performance on pollution control', protection of the ecosystem and operational environment.

For the oil and gas industry in particular, the concept of environmental reporting according to Guenther et al. (2006) is a key element of CSR because socially responsible oil and gas companies are expected to comply with and disclose the 35 indicators proposed by the Global Reporting Initiative (GRI). Moreover, environmental reporting by the extractive industries is a demonstration a commitment towards the promotion of sustainable development (Yongvanich & Guthrie, 2005) and particularly these companies are addressing sustainably the social and environmental impact of their operational activities in host countries and communities (Frynas, 2009). Table 1 provides a summary of some of the common environmental reporting indexes that have been used over time for environmental reporting by rating agencies and researchers.

There is a nexus between environmental behaviour and financial performance of companies. It is reported that employee CSR perception significantly influences environmental performance of organisations. Also, the mediating effects of employee pro-environmental behaviour and organizational citizenship behaviour towards environment (OCBE) were also found to be statistically significant (Channa et al., 2021). The implication of this is that both organisational citizenship behaviour towards environment and employee CSR perception have impact on environmental performance of organisations. Bednárová et al. (2019) investigated the relationship between environmental disclosure and environmental performance among the top 100 Fortune Global companies based on GRI indicators. It was found that there is a positive relationship between environmental disclosure and actual environmental performance. Furthermore, the effect of sustainability reporting disclosure on financial performance have also been reported in several empirical studies. For instance, Hardi and Chairina (2019) using the data of companies listed in both Indonesia Sustainability Reporting Award (ISRA) and Indonesia Stock Exchange (BEI) during 2016 and 2017 found that Economic Dimension Disclosure (EC) measured by GRI (Global Reporting Initiative) impact financial performance measured by Return on Assets (ROA). However, Environmental Dimension (EN) and Social Dimension (SO) do not affect financial performance on the listed companies. Similarly, Sumaryati and Rohman (2019) examined the relationship between sustainability reporting and corporate financial performance, as well as the relationship between Sustainability Reporting Disclosure Index (SRDI) and environmental disclosure using a sample of 52 companies listed on Indonesia Stock Exchange during the period of 2013–2017. The results suggest that sustainability reporting has an effect on both financial performance and environmental performance of the sampled companies.

Alazzani and Wan-Hussin (2013) evaluated the conformity of environmental practices of eight oil and gas companies with the Sustainability Reporting Guidelines of the Global Reporting Initiative (GRI), and found that the environmental reporting of these companies conformed with the GRI Sustainability Reporting Guidelines, which reflect and capture all aspects of environmental activities of the oil and gas companies. From the plethora of empirical studies reviewed above, it is observable that concerns about environment and environmental protection is growing among

Table 1 Spatio-temporal analysis of CSR measurements

SN	CSR measurement and variables	Proponents
1	**Environmental impact assessment (EIA)**: The EIA is a management tool for evaluating and reporting the future consequences and likely impacts of a proposed project or business operations on the environment and people before the action is taken. EIA is widely-used and recognised by international organizations and governments across the globe as a tool for managing sustainably and responsively the impacts of future development on the country's natural resource base	Clausen et al. (2011) and Wood (2014)
2	**ISO 26000 Standard (ISO Index)**: This is an international measurement with seven (7) core elements for evaluating the degree of compliance by firms with operational standards and social responsibility. It was adopted in Iran for evaluating CSR compliance. The seven assessment metrics include organisational governance, (i) human rights, (ii) labour practices, (iii) the environment, (iv) fair operating practices, (v) consumer issues, (vi) community involvement and (vii) development	Valmohammadi (2011)
3	**Dow Jones Sustainability Group Indexes:** This is the first global sustainability index that measures economic, environmental and social elements underpinning sustainability. It has been adopted by world-class companies across 68 industries and 22 nations. DJSGI prescribes technology, governance, shareholders, industry and society as the five (5) sustainability principles	Cerin and Dobers (2001) and Hawn et al. (2018)
4	**Sustainability Reporting Guidelines:** This is a global index developed by Global Report Initiatives (GRI) for measuring CSR disclosures and compliance with the ideals of sustainable development. The goal of sustainability reporting guidelines is to ensure that corporations play a crucial role in the society by focusing on the socio-economic needs of stakeholders. SRG has three key indicators, viz: Economic, Environment, and Social Performances/Disclosures	Charitoudi et al. (2011) and Alazzani and Wan-Hussin (2013)

(continued)

Table 1 (continued)

SN	CSR measurement and variables	Proponents
5	**Business in the Community Index:** This is a metric developed by a charity agency of the Prince of Wales called Business in the Community (BITC). The index measures the disclosure of CSR with focus on four (4) indicators, namely: Community, Environment, Marketplace and Workplace. While performance impacts indicators are evaluated by two (2) indicators: (a) Social Involvement and (b) Environmental Involvement	BITC Index (2012) and Cuccia (2020)

Source Compiled by the authors from a cross-section of reviewed literature

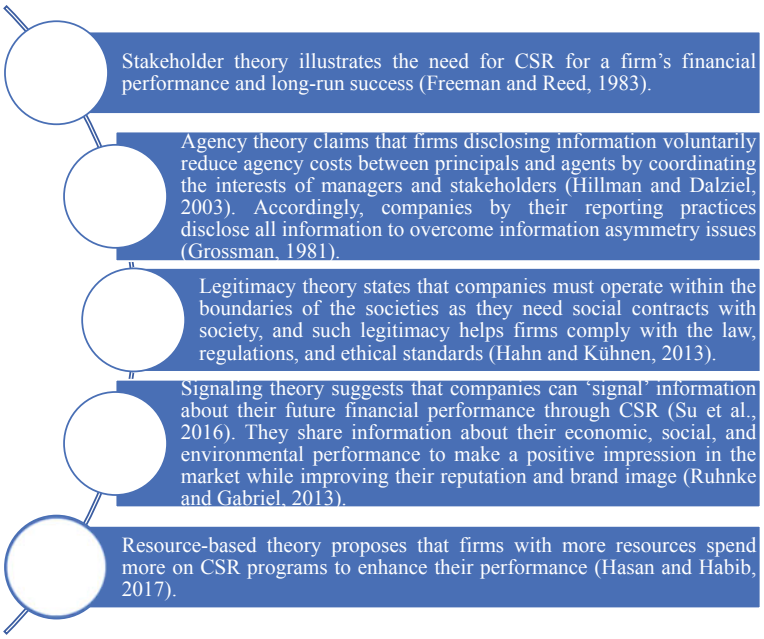


Fig. 1 Theories behind CSR reporting. *Source* Authors' elaboration based on Hasan et al. (2022)

stakeholders (Fig. 1), hence there is a direct and indirect impact of environmental reporting on environmental, social and financial performances oil and gas companies as well as non-oil and gas companies (Alazzani & Wan-Hussin, 2013).

3 Environmental Performance of Oil and Gas Companies

Studies confirm the positive effect of CSR committees on companies that operate in environmentally sensitive industries, including oil and gas companies (Bradbury et al., 2022). Oil and gas companies are expected to adopt corporate social responsibility through which they can protect biodiversity, avoid potential risks such as pipelines leakages, and prevent possible damage to the environment and people such as wastewater pollution and different type of emissions during the exploration, production and transportation processes (Kirat, 2015). In this way, stakeholders' and shareholders' demands could be satisfied. Although oil and gas firms are aware of different aspects of CSR—human and worker rights, anti-bribery and anti-corruption measures, ethics, and performance reporting, in practice, they do not always cover all dimensions but often address environmental issues (Kirat, 2015).

Corporate environmental performance is an organization's behaviour towards the environment, and how it measures and manages its ecological footprints (Tyteca et al., 2002). Companies attempting to use natural resources efficiently and control pollution evaluate their environmental performance in order to improve their performance but also for benchmarking and reporting (Delmas & Blass, 2010; Zheng et al., 2020). Research results suggest that corporations using more advanced technologies and more robust management will have better outcomes in environmental performance (Zheng et al., 2020).

Despite the increase in alternative or renewable energy sources (Troster et al., 2018), the world economy still highly relies on crude oil (OECD, 2020). Given the characteristics of their business operations, oil and gas companies are under increasing pressure from various stakeholders concerning their economic, ecological, and social performance (Laplume et al., 2008; Orazalin & Mahmood, 2018; Yang et al., 2011) although the industry is important for a country's economy (Frank et al., 2016). However, society is expecting that the companies introduce sustainability principles into their operations in order to minimize environmental degradation, pollution, and contamination, and instead conserve the ecosystem (Johnston et al., 2007). Moreover, they need to reduce their negative effects on humans, water, air, and soil (Jose & Lee, 2007). In addition, on-surface oil spills cause environmental contamination of the sea, the potentiality of which must be included in the environmental risk assessment (Crivellari et al., 2021).

The research on reporting practices of the oil and gas companies in Russia revealed that companies with foreign investments disclose more sustainability information than locally owned companies, and firms that provide sustainability reports in Russian share more information than those reporting in both English and Russian languages (Orazalin & Mahmood, 2018). This is important as study results suggest that foreign investors face difficulties to make decisions regarding companies that do not provide sustainability reports in English (Jeanjean et al., 2015).

Interestingly, profitable companies are more likely to disseminate more information transparently (Kansal et al., 2014; Ruhnke & Gabriel, 2013). The study also found that older companies issue more transparent sustainability reports (Orazalin &

Mahmood, 2018). Moreover, highly indebted companies tend to issue sustainability disclosures to make a positive impression and persuade their investors (Barako et al., 2006; De Beelde & Tuybens, 2015).

Corporate environmental performance is usually measured by 3 categories of indicators: (1) environmental impacts including emissions, pollution, energy use, toxicity, (2) regulatory compliance including violation fees, audits, and (3) management including organizational processes, reporting, environmental management system (Delmas & Blass, 2010; Ilinitch et al., 1998). Frank et al. (2016) identified key indicators while analysing the environmental performance of oil and gas companies: Freshwater withdrawal and Energy consumption into the Resources consumption category; Direct emissions and Indirect emissions included in the GHG emissions category; Nitrogen oxides (NOx), Sulfur oxides (SOx), and Volatile organic compounds (VOC) are into Other emissions category; Hazardous waste, Non-hazardous waste, and Oil spills belong to the Spills and Waste effect category. It is noteworthy that previous research found a negative correlation between emissions-based indices and the economic performance of companies (Wagner, 2005). Research results demonstrate that innovation regarding green products and processes is positively correlated to the financial performance of oil and gas companies in the USA and Europe and hence, ensures their long-term survival (Aastvedt et al., 2021). Study results indicate that CSR affects the environmental performance of companies and in turn, the environmental strategy improves environmental performance (Kraus et al., 2020). Thus, the oil and gas industry is engaged in CSR activities to decrease their negative environmental footprints and shape a better public image (Chowdhury et al., 2018).

Across the developed and developing countries, the oil and gas companies give serious attention to environmental reporting to avoid the legal penalties tied to environmental violations and such as sanctions, huge fines, damage awards to victims, remediation costs, and market value losses (Karpoff et al., 2005). The global oil and gas industry environmental disasters caused by socially irresponsible companies have had spillover negative impacts on the business ecosystems and health (Madsen, 2009); the spillover negative impacts of environment excesses affect the cash flow and reputations of companies responsible involved (Blanco et al., 2009; Karpoff et al., 2005; Klassen & McLaughlin, 1996; Porter & van der Linde, 1995).

4 Behaviour of Oil and Gas from Central and Eastern Europe

Companies in the oil and gas sector are among the most active entities in the field of non-financial reporting, considering the pressure exerted by stakeholders who follow very closely the activity of these companies and their impact on the environment and society. The scandals in which these companies were involved, either through the lens of large-scale financial fraud or from the perspective of greenwashing actions, made the published sustainability reports increasingly complex in the management

teams' desire to convince the stakeholders of the good faith of the companies that in initiating and promoting the principles of sustainable development. Moreover, the energy transition process in which the whole of humanity is involved brings into the center of attention the companies in the oil and gas sector that must reinvent themselves considering the competition exerted by the new renewable energy sources. In an attempt not to lose the start in this complex process that the transition to the economy with zero carbon emissions entails, these companies are also involved in the financing of projects that involve the production of energy from renewable sources (Andrei et al., 2017; Khan et al., 2022). The new geopolitical context in Europe generated by the invasion of Ukraine by Russia has caused the energy transition process to be in an extensive restructuring process considering the intensification of European countries' preoccupations for ensuring energy security. Therefore, in this landscape, oil and gas companies have become important actors in the process of ensuring energy independence that the European public authorities are pursuing, considering the major risks presented by limited access to energy—the reduction of production activities and the increase in energy poverty.

In order to analyse the non-financial behaviour of companies in the oil and gas sector, the companies from the basket of the CECE oil and gas index, calculated by the Vienna Stock Exchange, were selected. This stock exchange is a regional leader in Central and Eastern Europe and stands out for the launch of numerous indices that follow the evolution of companies in the area, there being both indices for a certain country or for a certain field of activity.

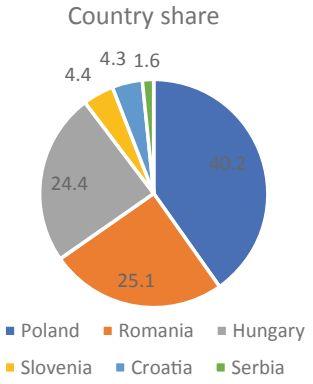
This index was launched in 2006 and tracks the evolution of ten representative companies listed at stock exchanges from Belgrade (Serbia), Bucharest (Romania), Budapest, Ljubljana, Prague, Sofia, Warsaw, Zagreb (Fig. 2). In addition, this index is also used as underlying asset for structured products and for futures & options. Even if the basket of the index is dominated by companies from Romania, Poland has the largest national share considering the stock market capitalization of the selected companies (Fig. 3).

The chosen research method was the content analysis of the sustainability, CSR or non-financial performance reports as well as the content of the companies' websites that have different sections such as "Sustainable Development", "CSR". These companies stand out for their high social involvement considering their character as listed companies (having leading positions on the national capital markets, being included in the category of blue chip companies) but also the membership of the European Union for most of the companies in the index basket, fact that generates the obligation to publish non-financial information according to Directive 95/2014 regards disclosure of non-financial and diversity information (Fig. 4) by certain large undertakings and groups (Felix et al., 2022; Panait et al., 2022a, 2022b; Vasile et al., 2022).

The identification of the most important areas in which companies are involved in order to maximize the value created for stakeholders supposed numerous meetings and consultations with them (Vasile et al., 2022), the result being the establishment of new material topics for the Sustainability Report and the materiality matrix (Fig. 5).

Fig. 2 The companies selected in the basket of CECE oil and gas index. *Source* Authors' elaboration based on data derived from CECE OIL EUR | Index | Composition: Vienna Stock Exchange (wienerborse.at)

Fig. 3 The countries share in the basket of CECE oil and gas index. *Source* Authors' elaboration based on data derived from CECE OIL EUR | Index | Composition: Vienna Stock Exchange (wienerborse.at)



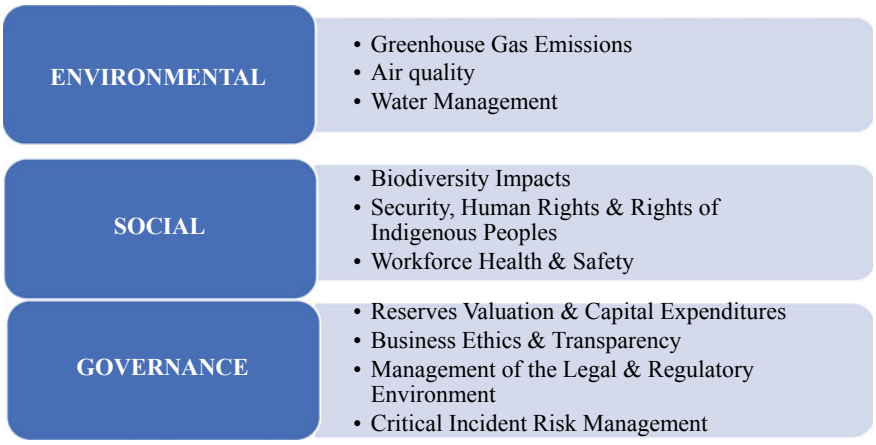


Fig. 4 ESGs topics of oil and gas companies. *Source* Authors based on public information of listed companies from CECE oil and gas index

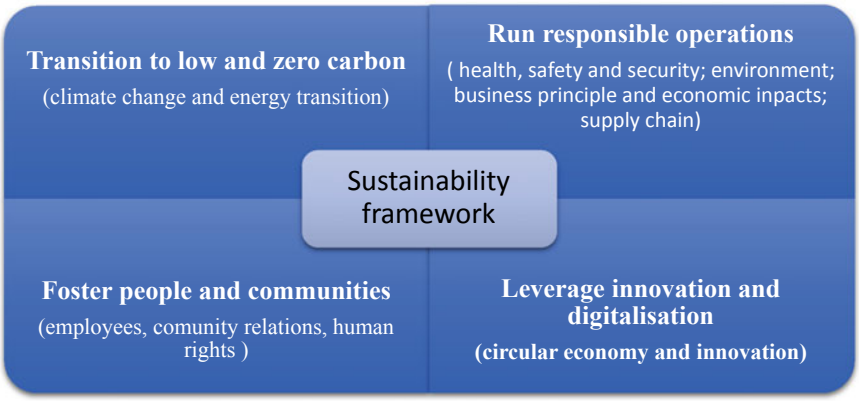


Fig. 5 Reporting on materiality. OMV Petrom case (2021). *Source* Authors' elaboration based on data derived from OMV Petrom Sustainability Report 2021

The role of leader in promoting sustainable development in the region belongs to the company PKN ORLEN, which follows not only the classic aspects regarding ESG, but which has set up a Green Finance Framework based on the International Capital Markets Association ("ICMA") Green Bond Principles ("GBP"), 2018 version 2 and Loan Market Association ("LMA") Green Loan Principles ("GLP"), 2021 version. Green Finance Framework is focused on non-fossil fuels projects, the main segments being renewable energy, clean transportation, pollution prevention and control (in order to promote the circular economy activities of companies, which is vital for economy [Hysa et al., 2020]).

5 Conclusions

The chapter is devoted to the study of the non-financial behaviour of oil and gas companies in Central and Eastern Europe. It answered the research questions regarding the main issues the companies of oil and gas from the basket of the CECE oil and gas index were reporting and explored the ways in which these companies were reporting. The oil and gas companies are very concerned about their non-financial performance, consulting stakeholders to identify aspects that are of interest to them, but also disseminating specific information regarding their environmental and social involvement. From simple CSR actions, these companies have developed sustainable development strategies that have generated the metamorphosis of their business strategies. Even if they operate in the field of fossil fuels, the energy transition is promoted by these companies as they are also concerned with the production of energy from renewable sources, financing specific investment projects in this sense. These companies not only promote sustainable business but also green finance using specific financial products such as green bonds for financing. The CSR programs run by these companies are far-reaching considering both the financial capacity of these companies and their desire to improve their image among stakeholders considering the negative externalities they generate through production activity. Unfortunately, in some cases, CSR programs are also used as a greenwashing strategy, the companies' intentions not always being to protect the environment but only to beautify their public image. Increasing the level of stakeholders' awareness, however, generates the appropriate actionable detection of these unethical behaviours by the stakeholders.

Thus, CSR and environmental performance reporting initiatives are significant for oil and gas companies for their success, image, and reputation and for promoting sustainability. Current global requirements regarding sustainable development goals and the topicality of renewable energy sources increase the demand towards non-financial reporting of companies. They should prioritize the reduction of greenhouse gas emissions, and water management and improve environmental performance while contributing to the SDGs. At the same time, companies need to consider employee health and safety, diversity in the workplace, human rights, and the impact of their operations on society while adopting ethical and responsible governance practices. Therefore, CSR and environmental performance reporting must avoid greenwashing while engaging in dialogue with different stakeholders.

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"Do No Significant Harm" Principle and Current Challenges for the EU Taxonomy Towards Energy Transition

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Abstract "Do no significant harm" to the environment is a European principle to which companies and financiers refer in all investment decisions, since in economic activity increased attention and respect for the environment must be shown. The "Regulation on taxonomy" takes into account the effect of an activity on the environment but also the effect on the environment of the products and services provided by the respective activity during the entire life cycle; it aims, at the same time, to stop the practice of "greenwashing"—with the meaning of presenting something harmful to the environment as beneficial to the environment. Regarding nuclear energy and natural gas, although there are controversies over the observance of the "do no significant harm" principle, they are considered strategically important for the energy security of Europe. Thus, both in the case of nuclear energy and natural gas, the activities must contribute to the transition to climate neutrality; in the case of nuclear power, activities must meet a set of requirements for nuclear and environmental safety. For Romania, the context of the application of the DNSH principle and the EU taxonomy had a particularly important stake for internal energy security, given that our country will invest, through the National Recovery and Resilience Plan, in natural gas pipelines also adapted for hydrogen, as well as in the expansion of activity in the field of nuclear energy.

Keywords Energy transition · Taxonomy · Do no significant harm · Decarbonization · Greenwashing · Nuclear energy · Gas

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1 Introduction

The "Do no significant harm" (DNSH) principle was established by (Regulation (EU) 2020/852) of June 18, 2020, entered into force on July 13, 2020. The "Regulation on taxonomy" provides that an economic activity is considered sustainable from the environmental perspective if it contributes substantially to 6 environmental objectives ("adaptation to climate change", "mitigation of climate change", "pollution prevention and control", "protection of water and marine resources", "circular economy", "biodiversity and ecosystem protection and restoration"), does not significantly prejudice any of these objectives and complies with the screening criteria set by the Commission.

In fact, the evaluation of an economic activity takes into account both the effects of the respective activity on the environment and the effect on the environment of the deliverables provided by the respective activity during the entire life cycle (production, the use and decommissioning of the products and services concerned). Therefore, in the sense of article 17 of (Regulation (EU) 2020/852), an economic activity significantly damages (1) the mitigation of climate change, if it generates substantial emissions of GESes; (2) adapting to climate change, if it negatively influences people and nature; (3) protecting water and marine resources, if that activity is harmful to the good condition or the good ecological potential of surface, underground and marine water bodies; (4) circular economy, if the activity produces inefficient use of materials or natural resources, including energy from non-renewable sources, as well as if it amplifies the problem of waste management; (5) prevention and control of pollution, if that activity produces a significant increase in pollutant emissions; (6) the protection and restoration of biodiversity and ecosystems, if the activity is harmful to the conservation and resilience of ecosystems.

The DNSH principle is a fundamental criterion for accessing funding from the Recovery and Resilience Mechanism (NextGenerationEU, 2021). The mechanism, in force since February 19, 2021, was established by (Regulation (EU) 2021/241) and finances reforms and investments in EU member states until December 31, 2026. The objective of this financial facility is to reduce the socio-economic impact of the crisis generated by the COVID-19 pandemic and to support the sustainability and resilience of European economies and societies, in view of the challenges generated by the green and digital transition. The inclusion of the DNSH principle in the ex-ante evaluations of the National Recovery and Resilience Plans (RRPs) of the member states implies that the proposed actions or economic activities that significantly harm any environmental objectives, in the sense of Article 17 of the "Regulation on Taxonomy" (Regulation (EU) 2020/852), they cannot benefit from financial support. The technical guidelines on the application of the "do no significant harm" principle under the Regulation on the Recovery and Resilience Mechanism (RRM) (Regulation (EU) 2021/241) provide that Member States must provide an individual assessment according to the DNSH principle for each measure within the plan, including those considered to contribute to the green transition. Concretely, within the RRM investments to increase the level of electrification in key sectors

(industry, transport, buildings) must be considered compliant with the DNSH principle in the field of climate change mitigation, provided that the member states in the EU space justify the fact that the level of electrification is accompanied by an increase in the capacity to generate energy from renewable sources at the level of each country.

The "Taxonomy Regulation" aims, at the same time, to stop the practice of "greenwashing"—with the meaning of presenting something harmful to the environment as beneficial to the environment—and to compel energy actors to publicize environmental, social and governance risks (Dusík & Bond, 2022) believes that the application of DNSH can change the mentality towards sustainable development expectations associated with policy instruments such as environmental assessment, and (Hakahuhta, 2020) believes that the importance of information on compliance with the "do no significant harm" principle could grow even more among non-financial information alongside human rights compliance and anti-corruption (Sweatman & Hessenius, 2020) argue that applying the EU taxonomy to 1,000 projects in the EU27 member states demonstrates that the Union's objective of investing 37% of the Recovery and Resilience Fund and 30% of the Next Generation EU in DNSH-aligned projects is feasible. Essentially, for (Piebalgs & Jones, 2021) this will also mean that 'green finance' will have to predominantly, if not exclusively, support commercial activities that are 'taxonomy compliant'. However (Schütze & Stede, 2021) show the need for a differentiation of criteria regarding new investments versus existing ones, as well as for activities that produce carbon emissions incompatible with the decarbonized future.

Ehlers et al. (2021) are of the opinion that the taxonomy can define a common understanding of economic activities that favor the economic transition, thus constituting an essential pillar of climate reporting and market transparency in general.

In this sense, to support the understanding of how to apply the technical examination citations in the case of the first 2 environmental objectives, the Commission has created a tool for easy documentation, by domains (EU Taxonomy Compass, 2021). In the field of Energy, reference is made to the application of the DNSH principle in the case of economic activities that contribute to mitigating climate change by generating electricity using solar photovoltaic technology, wind, ocean energy technologies, hydropower, geothermal energy, renewable non-fossil liquid and gaseous fuels, electricity, hydrogen, biogas, biofuels, energy transport networks, heat pumps.

The complementary delegated act of January 2, 2022 (EU Taxonomy, Complementary Climate Delegated Act, 2022) makes the case for the role of natural gas and nuclear power as a means of facilitating the transition to a future based mainly on renewable sources.

Prior to the regulation of the "do no significant harm" principle, the obligation to apply the strategic environmental assessment procedure existed based on (Directive, 2001/42/EC), decision which continues its legal applicability even today. The strategic environmental assessment (SEA) targets to identify and assess the environmental effects of programs, before their adoption and during the implementation. The SEA Directive was adopted in 2001 and had to be transposed by the Member

States into national legislation by July 2004. The application of the SEA aims at early signaling of options that do not ensure environmentally sustainable development, at the stage when alternatives major are still possible. Government Decision no. 1076/2004 transposes the SEA Directive into Romanian legislation and establishes the environmental assessment procedure for certain plans and programs, such as the programs financially supported by the EU. The environmental report marks the potential significant effects on the environment that the implementation of the plan or program in question might produce, taking into account its reasonable alternatives, the objectives and the geographical area of implementation, biodiversity, fauna and flora, water, air, climatic factors, soil, cultural heritage, population, human health, material values, landscape. The evaluations must also analyze side effects, positive and negative, synergistic, short, medium and long term, temporary and permanent. The environmental assessment for plans and programs must involve the following stages: framing stage; the domain finalization stage; drawing up an environmental report on the possible significant effects of the development proposal; carrying out a consultation regarding the development proposal and the environmental report; the decision-making process, which takes into account the environmental report and the results of the consultation; public transparency before and after the adoption of the decision; monitoring the implementation of the decision.

2 Energy Transition—A Challenge Generated by the Need to Protect the Environment

The implementation of the "do no significant harm" criterion occurs against the background of the sustained economic, political and diplomatic efforts of the states all over the world to achieve climate neutrality, in the conditions of the massive deterioration of the quality of the environment in the last decades.

Extreme weather and climate phenomena have caused financial losses of over 419 billion euros in the EU27 from the 1980s to the present, which is far more than the sums allocated by the European Union for all its programs within two years (IPCC Report, 2022), the transition to a climate-neutral economy representing an absolute necessity in the context of sustainable development (Apostu et al., 2022; Khan et al., 2022; Neacșa et al., 2022; Panait et al., 2022a). In fact, taking into account the complexity of creating a sustainable economy, with low carbon emissions, at the EU level, through central and local public authorities, we want a change in the behavior of companies and consumers in relation to the need to protect environment and the stronger promotion of sustainable development principles (Andrei et al., 2014; Felix et al., 2022; Gigauri & Vasilev, 2022; Morina et al., 2021; Noja et al., 2022; Popescu et al., 2022).

The UN Framework Convention on Climate Change, adopted in 1992 at New York and ratified by the European Community through (Decision 94/69/EC) of December 15, 1993, contributed to a greater awareness of the world public about aspects related

to climate change, establishing the principle of "common but differentiated responsibilities". On December 11, 1997, the Kyoto Protocol was adopted, which contained commitments by industrialized countries to reduce GES (GES) emissions by at least 5% between 2008 and 2012, relative to 1990 levels. The Protocol was signed by the European Community in April 1998 and approved by (Decision 2002/358/EC). Through the (Doha Amendment to the Kyoto Protocol, 2015), it is agreed to continue the commitments until 2020.

European statistics show that, in 2019, energy generated more than 77% of GES emissions in the EU, of which transport represents almost 33%. Agriculture contributes over 10%, industrial processes over 9%, waste management approx. 3%. In the top of the largest GES emitters are China, the United States, the EU, followed by India and Russia (European Parliament, GES emissions, 2021).

The Energy Union Strategy, launched on February 25, 2015 (COM/2015/080), aims to integrate member states in the energy sector, and the Energy Union Governance Structure, adopted on November 26, 2015 (EU Council Conclusions, 2015) places the energy transition in five major areas (pillars): energy security, energy efficiency, decarbonization, competitiveness and innovation, internal energy market. The Paris Agreement on Climate Change, December 12, 2015 (EUR-Lex—22016A1019(01)), the first legally binding global agreement, calls for the EU to become a climate-neutral economy and society by 2050 climate, it being established that, by 2030, zero-carbon solutions will be competitive in sectors that generate over 70% of global emissions, and in 2030 energy consumption from renewable sources will reach 32%.

The signatory parties agreed that the implementation of the Agreement requires economic and social transformations, with a view to achieving the objectives of reducing GES emissions to 40% by 2030, compared to 1990, of interconnecting the energy market electricity at a level of 15% by 2030 improving energy efficiency by 32.5% in 2030; of reaching a consumption of energy provided by renewable sources of 32% in 2030.

The 2030 Agenda adopted during the UN Summit for Sustainable Development in September 2015 (UN, A/RES/70/1, 2015), was assumed by the Europe (EUCO 8/17, 2017). The agenda contains 17 goals (SDGs) that aim to improve the life quality of citizens and protect the planet to meet the needs of nowadays and future generations. Objective 7 (SDG7)—Ensuring everyone's access to reliable, sustainable, modern and accessible energy foresees, until 2030, a significantly increased percent of renewable energy in the international energy mix; doubling the energy efficiency improvement coefficient globally; international cooperation for research and technology in the field of clean energy and for investment in energy infrastructure; sustainable services for all countries in line with support programs.

The evolution of the share of renewable energies at the European level has recorded until 2020, different progress at the country level compared to the proposed targets. The different dynamics are generated by significant differences regarding the endowment with natural factors, the involvement of public authorities but also the reaction of companies and consumers towards renewable energies (Andrei et al., 2017; Dusmanescu et al., 2016; Morina et al., 2022; Panait et al. al., 2022b). Thus, Eurostat data

show that Romania has reached its proposed objective at the level of 2020, the average at the European level not having been achieved due to important gaps at the level of the member states (Eurostat, Statistics on energy from renewable sources, 2021).

By adopting the legislative package "Clean energy for all Europeans" in November 2016, the European Commission places consumers at the center of the energy transition, for a way of using smart money (Cordea & Suciu, 2019). At the same time, EU energy diplomacy focuses on energy security and diversification and climate security (Foreign Affairs Council (10995/15) 2015).

To monitor the evolution of the 5 pillars of the energy union, the EU established the obligation for each of the member states to submit, by December 31, 2018, a National Integrated Plan for Energy and Climate Change for 2021–2030 (Regulation (EU) 2018/1999).

The European Council in December 2019 (EC Conclusions, 2019) recognized the right of each state to decide upon the energy mix at national level, also the appropriate technologies, and at the European Council of December 2020, the mandatory EU objective of net internal reduction of GES emissions was increased to minimum 55% by 2030 (European Council Conclusions, 2020).

The European Green Deal (COM (2019) 640 final) affirms the need for an economic growth decoupled from the use of resources, therefore the Investment Plan for a Sustainable Europe was launched in January 2020 and the establishment of the Just Transition Mechanism (P9_TA (2020) 0305). It will focus on financial allocations for the most vulnerable regions and sectors in transition, facilitating employment in new and transition sectors, as well as reskilling opportunities (Joița & Dobrotă, 2022). Through the "Green Deal", the EU takes on the ambitious goal of becoming the first continent with net zero GES emissions in 2050.

In the opinion of (Leonard et al., 2021a, 2021b), the EU's goal of climate neutrality by 2050 represents a revolution in the continent's energy habits, also involving important changes in Europe's diplomatic relations.

An overview of the share of green energy in the total global energy consumption in the coming years reveals not only an increase in it, but also a drastic reduction in oil and natural gas consumption (ECFR, 2021).

The "European Climate Law" of June 25, 2021 (Regulation (EU) 2021/1119) legislated the EU's goal of becoming climate neutral by 2050 and a common goal of net reductions in GES emissions greenhouse by at least 55% by 2030 compared to 1990. Without affecting efforts to reduce energy poverty, it is considered necessary to phase out energy subsidies incompatible with the objective of climate neutrality, especially for fossil fuels.

UN Climate Change Conference October–November 2021 (COP26, 2021) concluded on additional efforts to implement the Paris Agreement. At the EU level, developed countries have been invited to increase financial contributions to reduce climate change and to support developing countries for this purpose. This important conference gave the opportunity to declare some ambitious goals for the next decades. More than 100 nations, including China, USA, Canada, Russia, Brazil, Indonesia, UK have signed a pledge to end global deforestation by 2030, that includes nearly $20 billion in public and private funding. More than 40 nations have also committed

to phase out coal by the 2030s (or 2040 in poorer countries). This map includes states very dependent on coal, such as Poland, Vietnam and Chile. At the same time, the world's biggest coal-consuming countries, such as India, China, USA, Australia, have not signed the pledge. Additionally, more than 100 national governments, cities and major companies have signed a declaration to accelerate the transition to zero-emission cars and vans (by 2035 in major markets and by 2040 globally). Last but not least, in order to support South Africa's transition to clean energy away from coal the EU, the UK, France, Germany, South Africa and the USA and have announced the Just Energy Transition Partnership, with an initial commitment of $8.5 billion.

There are currently concerns about energy production in the medium and long term. Can there be an energy mix based 100% on renewable resources in the year 2050, which does not cause significant damage to the environment, or will there still be a need for the production of electricity from natural gas and nuclear fuels? It is a question whose answer experts from all over the world are working on, various scenarios being taken into account. European Council of Foreign Relations (ECFR, 2021) estimates show that the energy mix will involve an important percentage of energy produced from fossil fuels in 2030 (33%), and the energy produced from nuclear sources will remain at a percentage of approximately 17%.

Although with regard to nuclear energy and natural gas there are lively controversies over the observance of the DNSH principle, the two energy sources can be said to represent, for the time being, the security component of the functioning of the energy systems, alongside the green component, made up of the energies renewable (Felea, 2021).

3 "Do No Significant Harm", Nuclear Energy and Natural Gas

The International Energy Agency's report (IEA Report, 2021) "Net Zero by 2050" states that, along with hydropower, nuclear power is the largest source of low-carbon electricity today and provides an essential basis for the energy transition, so that by 2050, almost 90% of electricity generation is estimated to come from renewable sources, of which around 30% will come from nuclear energy (European Court of Auditors, 2017) records that, in 2015, nuclear energy represented 22% of heat and electricity production in the EU and 47% of low-carbon electricity, with 129 reactors in operation in 2017 nuclear in 14 EU countries. The mentioned analysis reveals the fact that, in 2015, the emissions generated by the burning of fuels came in a proportion of 72% from the coal industry, 20% from the natural gas industry, 4% from oil and only 4% from nuclear energy and renewable energies, in the context in which the last two mentioned sources produced 51% of the electricity and thermal energy in the 22 analyzed European states.

Member States have different policies regarding nuclear energy. In 2020, 13 EU countries had operational nuclear reactors.

In these 13 EU countries there were 109 nuclear reactors providing around 26% of electricity production. Nuclear energy contributes more than 50% to the so-called "clean electricity" of the EU. At the EU level, there are six nuclear reactors in various phases of construction: Finland 1, France 1, Hungary 2 and Slovakia 2. At the same time, eight other countries are considering the construction of new nuclear power plants: the Czech Republic, Bulgaria, Finland, Poland, France, Romania, Slovenia.

On the other hand, in 2011, Germany was determined to phase out nuclear power by 2022 within its energy transition steps (Federal Ministry of Foreign Affairs, 2017), France also decided to reduce its dependence on nuclear power (Agerpres, 2020) (European Commission, COM (2017) 237 final) recorded that 90 existing reactors in the European space have been closed, 3 of which have been completely decommissioned, and, by the end of 2025, it was estimated that more than 50 functional reactors in currently they will be closed.

A statistic from 2016 on the world map (Focus.it, 2016) showed that most nuclear reactors were under construction in East Asia, followed by Central and Eastern Europe.

Also, available data at the European level (Eurostat, 2017) show the important share that nuclear energy and natural gas have had, since the beginning of the 1990s, in the energy mix used for the production of heat and electricity in the EU countries. There is a constant evolution of the percentage held by nuclear energy, the discrepancy occurring with regard to natural gas, whose importance was growing significantly from the 1990s to 2015, with statistical peaks in the years 2005–2010.

In 2020, a group of technical experts on Sustainable Finance (TEG) working with European Commission concluded that nuclear power could contribute to reducing the effects of climate change, but called for more detailed assessment of the DNSH aspects to ensure that nuclear energy does not damage other environmental objectives, through nuclear and radioactive waste management (Council of the European Union, C (2022) 631 final).

In 2021, a Joint Research Center (JRC) published a technical study for the European Commission on nuclear energy from the point of view of DNSH criterion. The report, designated as "sensitive", concludes that no scientific basis has been identified to substantiate the hypothesis that nuclear energy would harm the environment and public health to a greater extent than other production technologies already included in the EU Taxonomy, the impact of nuclear energy being considered "mostly comparable to hydropower and renewable sources, in terms of non-radiological effects" (JRC Report, 2021). In order to address the impact of nuclear power on water consumption, the site selection and plant operation phases need a proper care. The mentioned report brings as an argument the indicator regarding the maximum number of deaths recorded in the last decades related to activities in the energy sector. Reference is made to the fact that the number of deaths recorded in nuclear energy management is lower than in other sectors, especially in hydropower and coal. It is observed, however, that the highest level of maximum impact/consequences is associated with nuclear activities.

The report shows that uranium mining and milling, nuclear power plant operation and spent fuel reprocessing are the phases of the nuclear power life cycle which

might have significant potential for radiological impacts on the environment and human health, but it argues that, with nowadays technology, appropriate measures can prevent or mitigate the potential harmful impact. Regarding radioactive waste, the technical assessment shows that, although there are still contrasting opinions, there is nevertheless a broad technical-scientific consensus on the disposal of this waste in deep geological formations, the necessary technologies being available. The experts conclude that, given that the safety of nuclear energy life cycle activities is regulated by law in Member States, such activities could be the authorized under the monitoring by independent authorities.

Moreover, at the EU level, nuclear energy issues fall under the Euratom Treaty (legislation on the safety of nuclear installations) (Directive 2014/87/EURATOM) and for the management of radioactive waste and spent fuel (Directive 2011/70/EURATOM).

The decision to include nuclear energy in the EU taxonomy was intensely criticized, both by the governmental bodies of several European countries, but also by civil society.

Thus, in a joint statement of November 11, 2021 (Joint Statement, Federal Ministry for the Environment, 2021), before COP26, officials from 5 European countries (Germany, Luxembourg, Austria, Portugal and Denmark) affirmed the "incompatibility" of nuclear energy with the "do no significant harm" principle and expressed their "concern" over the fact that the inclusion of nuclear energy in the Taxonomy would definitively affect the credibility, integrity and, basically, the usefulness of this regulation.

Recognizing the sovereign right of Member States to decide for nuclear energy within their national energy systems, the official signatories of the declaration express the fear that a significant number of investors in the international market may lose confidence in financial products marketed as "sustainable" if they had to take the risk that they could finance activities in the area of nuclear energy.

A report by the Öko-Institut (Pistner & Englert, 2021) shows that, in the European Commission's JRC report, the finding that nuclear energy would not be more harmful than other energy-producing technologies is not equivalent to the fact that it would not significantly harm in accordance with the Taxonomy Regulation. Assessing the risk of serious accidents in nuclear power plants exclusively based on the mortality rate indicator is not sufficient if other risk indicators with maximum consequences on the population are not taken into account, such as: acute and chronic diseases, genetic damage, difficulties in the supply of drinking water, economic costs, including costs for civil protection, remedial activities, evacuations and relocations; contaminated land; damage to fauna and biotopes; damage to the image of companies or industries.

One of the most well-known experts and authors in the energy sector (Sovacool et al., 2016), evaluates comparatively the risk of accidents in the energy sector, using real data of 686 cases from 1950–2014. Thus, nuclear, hydropower and wind energy are classified with "high" risk of accidents; hydrogen, biomass and biofuels are considered with "moderate" accident risk; geothermal and solar would present a "low" risk. 48.8% of accidents come from the wind power sector, 97.2% of all deaths

come from hydropower and the most expensive accidents are produced by nuclear power, meaning 90.8% of damages.

The Net Zero Asset Owner Alliance, an investor group, rejected in August 2021 any prospect of labeling fossil gas and nuclear power as being "green" (Bloomberg, 2021). Similarly, the "Principles for Responsible Investments" Initiative, with over 4000 signatories from the financial market, signaled in a position document (PRI Initiative, 2021) that the inclusion of gas and nuclear energy in the taxonomy would reduce investors' interest in stimulating sustainable investments and would increase the risk of "greenwashing".

Climate Action Network Europe, a coalition of NGOs fighting climate change, counting over 170 member organizations in 38 European countries, argues (CAN, 2022) that labeling nuclear energy as a "sustainable" activity it goes against the principle of taxonomy regulation, so that activities and investments can only be considered "sustainable" if they do not significantly harm the circular economy, biodiversity and pollution reduction objectives.

Even if the risks of catastrophic nuclear accidents were to be ignored, CAN considers it "obvious" that activities related to nuclear energy do not respect these key principles, due to the significant environmental and social hazards at all stages of the life cycle—from extraction to waste disposal nuclear (Greenpeace, 2021) states that nuclear power represents a "costly diversion" from the development of renewable energy and energy efficiency, bringing with it the risks associated with nuclear weapons proliferation and terrorism.

On the other hand, trade unionists from 9 European countries, including Romania, plead in favor of nuclear energy (Capital, 2021), emphasizing safe and quality jobs, as well as the fact that it represents the only source of electricity" clean" permanently available, regardless of weather conditions. In Romania, in 2022, nuclear energy has a share of 7.6% of the national energy mix for electricity production.

In the same direction, based on the intergovernmental agreement concluded between Romania and the United States for cooperation in relation to Romania's nuclear program, signed in December 2020 (Agreement between the USA and Romania, 2020), Nuclearelectrica will build, until 2027, in partnership with the American company NuScale Power, the first American Small Modular Reactor (SMR). The United States of America (US Embassy, 2021) states its "hope that the European Union will respond to the overwhelming request of the member states to include nuclear energy in the taxonomy for sustainable financing", given that, in the USA, nuclear energy produces approx. 55% of the total electricity generated without carbon dioxide emissions.

For Romania, the expansion of nuclear capacities at Cernavodă represents an energy security decision. Investments in Romania's nuclear projects are developed by SC Nuclearelectrica SA. Romania's energy strategy 2020–2030, with the perspective of 2050 (Ministry of Energy, 2020) provides for construction of two new reactors (Unit 3 and Unit 4 at the Cernavodă nuclear power plant), at the level of 2030, under conditions of economic efficiency and compliance with the technical and environmental conditions agreed at European level. In addition, the refurbishment of Unit 1 (Cernavodă NPP) is planned for 2028. It is estimated that starting from 2025, the

production of electricity from nuclear sources will end up doubling in Romania, while the production of energy from coal will decrease by about 25%.

From the perspective of the energy source from natural gas, over the past two decades natural gas has provided an increasingly important share of Europe's energy needs (in contrast to others oil and coal, whose importance has declined), now representing nearly a quarter of gross domestic energy consumption, especially for electricity generation and home heating (EU Parliament Infographic, 2017).

Romania is one of the EU member countries with the largest domestic production of natural gas, to which is added the exploitation, in the near future, of a major gas deposit in the Black Sea. At the level of the EU, Romania has the third largest natural gas reserve, ranking right after the Netherlands and Great Britain. Currently, natural gas provides approximately 40% of Romania's energy consumption (DistrigazSud, 2022).

In the perspective of the years 2030–2050, the country's energy strategy (Ministry of Energy, Energy Strategy of Romania) emphasizes the development of energy production capacities from renewable energy sources and from sources with low emissions of GESes, ensuring, in this thus, a balanced and diversified energy mix, although the share of natural gas is estimated to remain around 20%.

Meanwhile, the Delegation of the European Parliament at COP26 argued (Euractiv, 2021) that nuclear energy and gas can be introduced in the EU taxonomy, but under strict conditions and not as green energies, but in the transition category.

This position also follows the fact that, in July 2020, the European Commission proposed a hydrogen strategy (COM/2020/301 final), which aims to accelerate the production of renewable hydrogen. Although hydrogen currently accounts for less than 2% of Europe's current energy consumption and is still largely produced with the help of fossil fuels, the widespread use of "green" hydrogen could be an essential step towards a neutral Europe from a climate point of view, an objective that the EU wants to achieve by 2050 (European Parliament Report (P9 TA (2021)0241)).

On February 2, 2022, the European Commission presented the complementary Delegated Act on climate taxonomy (European Commission, 2022), which, based on art. 10 para. (2) of the Taxonomy Regulation, establishes clear and strict conditions subject to compliance with which certain activities in the nuclear and natural gas sectors can be included as transitional activities alongside those already covered by the first Delegated Act on climate change mitigation and adaptation, applicable from January 1, 2022 (European Commission, 2021). Thus, considering nuclear energy and natural gas activities, they must contribute to climate neutrality transition; in the case of nuclear power, activities must meet a set of requirements for nuclear and environmental safety. The provisions would apply starting from January 1, 2023, if no objections are registered from the co-legislators (the European Parliament and the Council).

As a natural follow-up for COP 26, the 27th United Nations Climate Change Conference (COP 27, 2022) took place on November 7–8, 2022, in Egypt, which holds the COP27 presidency. At COP27, parties declared once again the desiderate to accelerate global climate action while ensuring that no one is left behind. In addition, the conference brought the parties together to agree on the United Nations Framework

Convention on Climate Change (UNFCCC). The COP27 conference had four major objectives related to climate change: mitigation: maintaining the objective of 1.5 °C in terms of global warming, compared to pre-industrial levels; adaptation: establishment of a consolidated global action agenda in the field of adaptation; financing: assessing progress in providing $100 billion every year by 2025 for developing countries to help them deal with the negative effects of climate change; cooperation: ensuring adequate representation of all relevant stakeholders at COP27.

Basically, the Environment Council, through EU environment ministers, on October 24, 2022, approved a general EU negotiating position for the 27th United Nations Climate Change Conference (COP 27). In order for the proposed objectives related to climate change (specially to mitigate global warming) to be achieved, the position adopted by the EU requested—the collective consolidation of the contributions established at the national level—for all parties to end the use of coal-based energy without reducing emissions, through a gradual phase-out, and to end inefficient subsidies for fossil fuels—all countries to step up their efforts to mobilize finance to support climate action.

The EU, through its institutions, also wants to work with stakeholders to; to encourage the discussion on the future of the UNFCCC; to discuss the sustainable implementation of climate actions in the agricultural sector; enable the implementation of the Glasgow Work Program on Climate Capacity Action; to address the gender dimension.

At the same time, the EU Environment Council adopted on October 28, 2022, proposals and measures regarding the financing of the fight against climate change. The goal is to meet the global commitment to mobilize USD 100 billion per year by 2025 to assist developing countries cope with the effects of climate change.

4 DNSH Assessment and European Funding for Energy Transition

The DNSH principle has been adopted in all European funding regulations. Thus, the programmatic documents of the Recovery and Resilience Mechanism (RRM) (Regulation (EU) 2021/241), the Just Transition Fund (Regulation (EU) 2021/1056) and the European Regional Development Fund/Cohesion Fund (ERDF/CF) (Regulation (EU) 2021/1060) provides for the financial support granted to activities that respect the climate and environmental objectives, the priorities of the Union and the principle of "not to prejudice significantly" in the sense of art. 17 of Regulation (EU) 2020/852—EU Taxonomy.

In the proposed revision of the Trans-European Networks for Energy (TEN-E) Regulation (European Parliament, EU Guidelines, 2021), the European Commission emphasizes decarbonization, with increased attention to offshore energy networks electricity, hydrogen infrastructure and smart grids. The new rules for TEN-E will support the EU's climate goals and the Green Deal, so that in future new projects

involving fossil fuels will not benefit from funding from the Connecting Europe Facility. The Commission's proposal includes the obligation, for all projects, to comply with the "do no significant harm" principle.

Basically, the regulation decides to no longer finance new initiatives involving natural gas and oil and to introduce mandatory sustainability criteria for all projects, but to allow, during a transition period that will end on December 31, 2029, the use of assets dedicated to hydrogen converted from natural gas for the transport or storage of predefined mixtures of hydrogen with natural gas or biomethane. As a transitional measure, the regulation will support projects connecting regions isolated from European energy markets, projects to develop cross-border interconnections and to enhance collaboration with non-EU countries.

Returning to the RRM, the technical guidelines regarding the "do no significant harm" criterion require Member States to accompany each measure provided for in their recovery and resilience plan (RRP) with an assessment according to the DNSH principle (European Commission (2021/C 58/01)). No investment or reform should cause significant damage to the environmental objectives, otherwise the Commission cannot assess the RRP positively. Reforms in some areas, such as energy, although it is estimated that they could contribute significantly to the green transition, may also present a risk of causing significant harm in relation to environmental objectives.

Compliance with applicable EU and national environmental legislation—such as strategic environmental assessment (SEA) in accordance with Directive 2001/42/EC—is a distinct obligation and does not remove the DNSH assessment, as the approaches are not identical to those provided in Article 17 of the Taxonomy Regulation ("Significantly harming environmental objectives").

Procedurally, in a first step, Member States have to complete the checklist to mark which environmental objective(s) among the six require a substantive assessment of the measure according to the DNSH principle.

In the following step, for individual measures in the plan, Member States have to use part 2 of the checklist to carry out a substantive assessment according to the DNSH principle regarding the environmental objectives for which the answer "yes" was selected in stage 1. The Commission may find a certain measure associated with a possible significant harm to some of the environmental objectives in the situation where no adequate substantive justification can be built.

The technical guidelines acknowledge that electricity production is not yet a climate-neutral activity at EU level. However, those investments should be accepted in accordance with the DNSH principle if the Member States justify the fact that the increased level of electrification is accompanied by an increase of the capacity to generate energy from renewable sources. Member states must demonstrate as well that these measures do not significantly harm the other five environmental objectives. With regard to natural gas, the Commission specifies that financing the electricity and/or thermal energy may be granted exceptionally, as countries are facing important challenges in the energy transition, but only if it contributes to the EU's decarbonization targets for 2030 and 2050. Furthermore, projects for the transport and distribution of gaseous fuels infrastructure can only be accepted if they allow the transport and/or storage of renewable and emitting gases low carbon dioxide.

For Romania, obtaining financing for the development of the natural gas network represented a big stake in the negotiation of the National Recovery and Resilience Program, our country having to show how the "do no significant harm" criterion will be respected in the implementation of the actions. Romania proposed, in the initial versions of the PNRR, a project regarding the connection to natural gas networks of hundreds of localities, for which it requested 600 million euros. Initially, the European Commission rejected this project, explaining that it will not accept polluting projects (Ionescu in G4media, 2021). Later, however, the Government modified the project so that the pipelines would carry gas in combination with hydrogen, 20% hydrogen initially, then gradually the amount would increase to 100%. Therefore, Romania will be able to finance the construction of gas pipelines through the National RRP, in the Oltenia region, the pipelines to be designed for the gradual injection of hydrogen. The network will transport 100% renewable and decarbonized gas in 2030, thus ensuring the principle of "not significantly harming" the environment (PNRR, 2021).

In the financing segment for energy transition in Romania, the Large Infrastructure Operational Program (LIOP—POIM, in Romanian) 2014–2020 went through the Strategic Environmental Assessment (SEA) procedure in accordance with the provisions of GD no. 1076/2004, the environmental report being developed in the ex-ante evaluation of the program (LIOP environmental report 2014–2020). Thus, the report shows that, in the case of non-implementation of the 2014–2020 POIM, the lack of investments in intelligent energy transport systems, in alternative solutions for heating homes, as well as the maintenance of industrial activity in the energy sector without measures to reduce pollution will maintain the level of emission of GESes.

Also, in the absence of appropriate systems for monitoring the energy consumption of industrial consumers, as well as of appropriate electrical networks for the transport of energy and natural gas, important economic losses will be recorded in terms of energy efficiency. From another perspective, the report shows that the lack of development of new transport networks for electricity and gas will exclude the possibility of the existence of elements that affect the landscapes.

At the LIOP 2014–2020 level, the allocation for development projects of intelligent natural gas distribution networks is 235.29 million euros. The value of the projects submitted under this call is 2.5 billion euros, with 219 projects being evaluated (MIPE, POIM, 2022). The projects aim at smart tools in the field of gas network infrastructure and the acquisition of integrated IT technologies.

Under (Partnership Agreement, 2021) for 2021–2027, the operational programs financed by the Cohesion Policy are subject to SEA Directive, 2001, so that a strategic environmental assessment is carried out for each program that could have a significant negative impact on the environment. At the same time, the Agreement also provides for the evaluation of "do no significant harm" at the level of the actions provided for in the operational programs, using the evaluations for similar interventions within the PNRR, according to the Technical Guidelines on the application of the principle of "do no significant harm" based on the Regulation on RRM (European Commission (2021/C 58/01)).

The Regional Operational Program 2021–2027 (POR, 2021) will finance specific actions aimed at improving, expanding and creating green infrastructures; increasing energy efficiency; improving mobility and clean urban infrastructure, etc., taking into account, when checking the eligibility of projects, the principle of "do not significantly harm".

Also, the Sustainable Development Operational Program (PODD, 2021) will address the challenges and deficiencies identified in the recent Country Reports and the implementation of the European Semester decisions, through investments in energy efficiency and reducing carbon emissions, environmental protection and combating and adapting to climate change, contributing to the realization of the objectives of the European Ecological Pact to transform the EU into a modern, competitive and efficient economy, decoupled from the use of resources. Action 4.5 of PODD—finances the conversion and modernization of the existing natural gas transport and distribution networks to the Smart Grid and hydrogen-ready dual standard (including by replacing pipelines incompatible with hydrogen transportation), and the "do no" principle will be taken into account when selecting projects significant harm".

5 Conclusions

Although strategic environmental assessments at the European level have established the neccessity to evaluate how economic activities would impact the environment, the principle of "do no significant harm" comes with the perspective of a "360° assessment", given the massive deterioration of environment quality in recent decades.

The DNSH principle is an eligibility criterion for accessing RRM. Within applying the EU taxonomy Romania obtained the agreement from the EU to invest, through the National Recovery Plan and Resilience, in natural gas pipelines also adapted for hydrogen, and also the country signed a partnership agreement with the United States of America for the expansion of activity in the field of nuclear energy.

The question of whether in 2050 an energy mix based that does not cause significant damage to the environment would be achievable remains a topic to which specialists and decision-makers from all over the world are trying to find the right answer, under the strong pressure of multiple socio-economic factors that shape political desiderates.

Although the issues related to nuclear energy and natural gas rise to divergences on the DNSH principle, the two energy sources ensure, for the time being, the security component of the operation of the European energy systems, as that estimates show that, in energy mix in 2030, a percentage of 33% will still go to energy produced from fossil fuels and 17% to nuclear energy. Even if estimates up to 2050 support the probability that up to 90% of electricity will come from renewable sources, there still remains a share of around 30% that will be due to nuclear energy.

Member States have adopted different policies regarding nuclear energy. The report of the European Commission's Joint Research Center (JRC) came, in March

2021, with the controversial conclusion that nuclear power would not harm human health or the environment to a greater extent than other electricity technologies already included in the Taxonomy EU, although real situations have shown, however, that nuclear activities are associated with the worst consequences on the population and ecosystems in case of accidents. On the other hand, states ensure the security of nuclear installations and the management of radioactive waste under the Euratom Treaty, which could constitute a guarantee on the quality of the management for this energy source.

These aspects were not convincing enough for the governmental bodies of several European countries and civil society, which harshly criticized the decision to include nuclear energy in the EU taxonomy. One of the fears of the appellants takes into account the decrease in the confidence of investors on the international market in the financial products presented as "green" if this would be associated with the risk of "greenwashing".

According to the World Economic Forum's "Global Risks Report 2022," a disorderly climate transition will worsen inequalities. "Climate action failure" has been identified as the main long-term threat, with the potential to have a severe global impact over the next decade (WEF, 2022). Countries that continue on a path of dependence on carbon-intensive sectors risk losing their competitive advantage due to a higher cost of carbon, reduced resilience or failure to keep pace with technological innovation. For the transition to a low-carbon economy, there are proven technological solutions that can be implemented on a large scale, and others are under development.

On the other hand, the authors of the report "Climate Change 2022: Impacts, Adaptation and Vulnerability", published by the IPCC in February 2022, showed that human-made climate change has already caused widespread negative effects, as well as significant damage to nature and society human (IPCC, 2022). The EU institutions are firmly committed to taking on the most ambitious targets. Therefore, EU Member States must maintain an extremely alert pace in transposing European legislation, formulating positions well-founded on scientific evidence, generating quality data, reporting and monitoring progress towards targets and attracting as effectively as possible the European funds available for the "green" transition. The European Commission's proposals to reduce net GES emissions by at least 55% (the "Fit for 55" principle) by 2030, compared to 1990 levels, have led to EU policy adaptation processes in various areas, such as energy, transport, agriculture, taxation, etc.

Societal and behavioral change is a vital part of achieving the climate neutrality policy for both Romania and other countries. Thus, the Committee on Climate Change suggests that millions of people will have to make changes in how they travel, how they heat their homes and how they consume food and other products. But these changes depend not only on them, but also on the availability of alternatives (for example, replacing the internal combustion car with an electric one).

The climate transition can generate not only a clean and healthy environment, the prevention of extreme weather phenomena and associated natural disasters, but also broad access to clean energy, "green" economic growth and new jobs. To benefit

from the positive effects of the transition, we need to harmonize diverse interests in an integrated approach, guided by science and expertise, in response to COP26 and the "Fit for 55" package.

From Romania's perspective, the expansion of nuclear capacities at Cernavodă represents a strategic energy security decision, given that the 25% decrease in coal-fired power production starting in 2025 can be offset by the doubling of electricity production from nuclear sources. And with regard to natural gas, Romania has specific interests, given that our country is in 3rd place in the EU in terms of domestic production, to which will be added the exploitation of an important gas deposit in the Black Sea.

The provisions of the complementary delegated Act on taxonomy in the field of climate from February 2022 brought a predictable compromise in the application of the DNSH criterion, but necessary on the path of the transition to climate neutrality.

For our country, obtaining financing for the development of the natural gas network represented a high stake in the negotiation of the National Recovery and Resilience Program. Romania's project approved in 2021 by the European Commission convinced the European decision-makers that it "does not significantly harm" the environment by the fact that pipelines capable of transporting gas in combination with hydrogen will be built, in a proportion that will gradually increase from 20 to 100% by 2030.

Similar to the PNRR, the operational programs from the 2021–2027 programming period in Romania financed from non-reimbursable funds are subject to strategic environmental assessments, including DNSH criterion of the actions proposed for funding.

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Agroecology, Service-Learning, and Social Responsibility: A Case Study for Spain

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Abstract Service-Learning (SL) is one of the most innovative approaches in education. This method seeks to apply the theoretical knowledge learned in the classroom through services to the community. At the same time, the growing concern for more sustainable and environmentally friendly agricultural production systems has brought this reality into the classroom. Therefore, at the university level, there are experiences of SL with an agroecological perspective channeled through internships in companies in master's degree programs. This article aims to analyze whether the participation of these companies in SL activities has been a positive or negative strategy and whether its management has been carried out in a controlled manner. The Balanced Scorecard methodology will be used for this purpose. The results obtained are heterogeneous, being particularly good in the "customers" factor, but reaching worse figures for the "Learning and Growth" factor.

Keywords Service-learning · Agroecology · Balanced scorecard methodology · Economic and financial analysis

1 Introduction

It is widely recognized that the university environment is a strategic instrument for promoting a more equitable and just society (Willems & Bossu, 2012). The World Declaration on Higher Education for the Twenty-first Century: Vision and Action, endorsed by UNESCO, spells out the missions and functions of higher education. Article 2 states that "higher education institutions, staff and students should (…)

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use their intellectual capacity and moral prestige to actively defend and disseminate universally accepted values, in particular peace, justice, freedom, equality and solidarity, as enshrined in the Constitution of UNESCO". It also states that university education should "(…) contribute to protecting and consolidating the values of society, ensuring that young people are inculcated with the values on which democratic citizenship rests and providing critical and objective perspectives in order to encourage debate on strategic options and the strengthening of humanistic approaches" (Gámez & Aldás, 2012; Tennant et al., 2009; UNESCO, 1998). Therefore, educational practices must create an institutional framework that promotes positive social practices of agents. This institutional framework can be created through formal rules, such as laws and regulations, or informal rules, such as methods and customs. The institutional framework determines the incentives that agents have and, if well designed, reduces transaction costs and increases exchange. Just as the institutional framework is important in sectors as diverse as fisheries (Caballero-Miguez & Fernández-González, 2015; Fernández-González et al., 2021), transport (Fernández-González et al., 2022) and energy (Álvarez-Díaz et al., 2017), it is also important in the education sector.

The approach of a pedagogy focused from socio-cultural transformation towards more responsible citizenship with their environment is a necessity in the new EHEA (The European Higher Education Area) (Kreber, 2010; Whiting et al., 2018). The Bologna objectives for the EHEA characterize the service-learning process as one of the main ways to obtain competencies (Dlouhá et al., 2019; Hinojosa-Pareja & García-Cano, 2020). Therefore, it is important to establish methodological proposals in which students are made aware of environmental issues, as well as to train them curricularly to generate critical treatments of the social scenario in which they interact (Olmos-Gómez et al., 2019; Reis, 2014). Providing students with analytical tools to detect the complexities involved in efficient ecosystem management is a top educational priority (Annamma & Morrison, 2018; Leal Filho et al., 2018; Suárez et al., 2018; Vandermeer & Perfecto, 2017).

The momentum of the methodology promoted through Service-Learning (SL) in the last two decades is undeniable (Phillips, 2011; Santos Rego et al., 2021). Although the precursors of this practice are to be found in the American continent first the United States and then the rest of South America, this educational approach has spread to Europe with notable success (Daynes & Longo, 2004; Servia et al., 2020). Its credit is due to the fact that it encourages the participation of the educational population in the social and community life in which they find themselves, being able to actively engage in conflict resolution through previously acquired knowledge (Bringle & Hatcher, 1996; Wurdinger & Allison, 2017).

Therefore, ApS is a dual tool. On the one hand, it enhances the reinforcement of learning carried out in the classroom and, on the other hand, it strengthens transversal competencies while developing the social ethics of both the students and the organization to which they belong (Kezar & Rhoads, 2001; Resch & Schrittesser, 2021).

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This feature fosters the social and civic responsibility of educational institutions while formalizing the commitment to active academic learning (Lough & Toms, 2018; Martinez, 2008).

In Spain, the practice of ApS in higher education has been timidly implemented. Part of the moderate penetration is due to the lack of funding to carry out student internships. However, where an increase in ApS experiences is being noticed is in third cycle university education (Meijs et al., 2019). This fact is due to the fact that part of the masters, more recurrently in those of a professional nature, internships are carried out. It is in these internships where the practice of ApS is developed. For this, there must be agreements between university institutions and companies. This is the case of a Spanish master's degree in agroecology, whose internship collaboration agreement extends its internships to a number of firms located in the east and south of Spain.

The growing importance of sustainability in economic production has made agroecology an increasingly widespread alternative to intensive agriculture. In an agriculture dominated by increasing and cheapening production, agroecology advocates the regulation and application of more environmentally friendly agricultural techniques, where the inputs used are of a renewable nature and where agricultural techniques are adapted to local resources (Norgaard, 1987). Agroecology also assumes the importance of other non-biophysical factors, such as political decisions, cultural determinants and the institutional environment. Indeed, although the dynamics of an agroecological system are influenced by biophysical elements, one cannot deny the great importance of market behavior, political decisions or the technology applied to that crop. In fact, the great complexity of the highly industrialized societies to which we have evolved was not reflected in the limited study of agricultural production processes, so this holistic vision is more appropriate for the study of ecosystems influenced by human intervention (Gliessman, 1998).

On the other hand, the empirical character of this science encourages us to banish the homogenizing development of agriculture, whose maximum objective is progress based on the maximization of profit and the accumulation of wealth (Orr, 2002). The study of the links between agrarian and cultural processes will lead to an adequate understanding of agrarian realities, which will help to achieve the prescription of conservation policies and respect for the ecosystemic environment (Rosset & Altieri, 1997).

The objective of this article is to determine, through the application of the Balanced Scorecard methodology, whether the management and results derived from the agroecological service-learning experience have been positive for the company. In this way, the vision, strategy and objectives to be followed by the company with regard to the experience are presented and, subsequently, indicators are developed to measure the achievement of the strategic plan.

2 Theoretical Framework

The theoretical framework used in this work is the result of the union of two of the most lively lines of research in the academic field. Both have undergone a profound advance, both in terms of empirical experiences and innovative theoretical developments: agroecological science and the practice of ApS.

2.1 The Importance of Agroecological Science Development

Agroecological science is a theoretical approach that can be defined as "the science that studies the structure and function of agroecosystems from the point of view of both their ecological and cultural relationships" (León Sicard, 2010). Therefore, this environmental science not only focuses on the efficiency of productive analysis, but also incorporates an environmental and social perspective to the cropping system. This vision on ecological sustainability implies the incorporation of a large number of characteristics to the critical agroecological analysis. This science presents a multidisciplinary approach incorporating concepts, techniques and theories from ecology, biology, anthropology, economics or sociology (Altieri, 2018; Van Hulst et al., 2020). Proof of this is the growing importance of variables such as the degree of adaptation to the natural environment, predation and competition (Hecht, 1999).

In order to understand the origins of this discipline, it is necessary to go back to the surprising development and great expansion of agriculture, intensified by the increase in population and per capita consumption worldwide since the 1950s. These demographic circumstances were accompanied, in turn, by a growing demand for food products, which led to the implementation of a whole series of technical agricultural improvements in order to meet society's needs and combat the problem of world hunger.

In this context, it is worth mentioning the vital importance of the phenomenon known as the "Green Revolution, a movement advocating that the existing famine was a consequence of a problem of low crop productivity, as the genotypes used for agricultural activity were not sufficiently resistant to fertilizers (Sarandón & Flores, 2014). For this reason, certain rice and wheat varieties were introduced and disseminated, combined with the use of novel agricultural techniques, including the continued use of pesticides and fertilizers (Hedden, 2003), leading to a massive increase in the production of these cereals with a high yield potential.

Due to this phenomenon, agriculture gained enormous influence to the point that it ended up occupying a large percentage of the earth's surface. Moreover, human needs were more easily covered due to the constant technological innovations experienced in this field, which facilitated productive intensification (De la Fuente & Suárez, 2008). However, these advances in agricultural activity were accompanied by a series of consequences, mainly referring to the fact that the use of natural resources to satisfy the food needs of the population is done at the expense of the planet and

environmental deterioration. Moreover, in this context, the paradigm shift imposed by the Green Revolution meant that the phenomenon of photosynthesis, by which plants transform light energy into chemical energy, became highly dependent on the supply of certain resources that are not considered fully renewable (Sarandón & Flores, 2014).

Therefore, on the one hand, the continuous technological development experienced by this discipline may appear to offer a certain stability to the agricultural system itself, as well as to the quality and quantity of its services. However, the economic, social and technological impacts of new agricultural production techniques can lead to questions about the sustainability of the agricultural system. However, due to the slow rate of environmental deterioration produced by these techniques, the impacts of these techniques at the ecological level are initially imperceptible. This deterioration, according to De la Fuente and Suárez (2008), is a consequence of the alteration of various elements, including biogeochemical cycles; land use, through the replacement of forests, grasslands and wetlands in favor of agricultural sites; biodiversity at a global level, encompassing genetic diversity within populations and the diversity of ecosystems linked to a landscape; and the dispersion of living organisms as a result of human activity.

On the other hand, on a social level, according to Brym and Reeve (2016), once the crops are harvested, a huge amount of the calories produced are destined for animal feed or biofuels, and even become waste that is never used. The fact that urban centers are moving away from farmland is the cause of a population that is becoming less and less familiar with agricultural activities, leading to a reduced awareness of healthy eating and, in parallel, an increase in diet-related diseases.

Therefore, the above arguments are useful to determine that, although the Green Revolution was an innovative movement that boosted agricultural production and productivity, the social and environmental problems it entailed cast doubt on its sustainability. This is why, over the years, the need has arisen to develop new agricultural models that contribute to the improvement of this system. It is in this context that agroecology emerges, an alternative based on the principles of ecology, evolution and equality as evaluators of agricultural practices and the success derived from food distribution (Brym & Reeve, 2016).

The term "agroecology" emerged at the beginning of the twentieth century, first used by the Russian agronomist Bensin, to refer to the use of ecological methods in agriculture (Wezel et al., 2009). Later, between 1930 and 1960, several authors used this area of research to present their results, but without explicitly referring to the term "agroecology".

However, from this preliminary view of agroecology, its definition and scope of application have evolved considerably over the course of history and have gained considerable recognition in recent decades. Today, agroecology is not only conceived as the application of agroecological concepts and principles but is based on a wide range of perspectives that differ in terms of academic content, research methodologies, and policy and practical applications. Moreover, this science presents a multidisciplinary approach that incorporates concepts, techniques and theories from ecology, biology, anthropology, economics or sociology (Altieri, 2018; Van Hulst

et al., 2020). Proof of this is the growing importance of variables such as the degree of adaptation to the natural environment, predation and competition (Hecht, 1999).

Consequently, according to Gallardo et al. (2018), some see agroecology as a science, a social movement or an agricultural practice; others see it as a transdisciplinary, participatory and action-oriented approach; and still others advocate the idea of adopting this discipline as a political action. It is this triple dimension that makes agroecology a discipline clearly opposed to conventional agronomy and a social movement focused on small farmers.

Indeed, in relation to the latter, Holt-Giménez and Altieri (2013) state that, with the Green Revolution, a huge number of small farmers were negatively affected by the increased power of larger and wealthier farmers. Around 70% of the planet's agrobiodiversity was lost from agriculture. In this context, agroecology provided a refuge for small farmers seeking land restoration. In this sense, agroecology is an obstacle to the technologies developed in this revolution because the cultural and ecological foundations of agroecology as a science derive from traditional agriculture, and therefore, instead of external inputs, the focus is on small-scale farms with a high level of diversification.

Agroecology is therefore defined as an alternative that provides a much more environmentally oriented and socially sensitive perspective on agriculture. Consequently, this discipline is strongly opposed to any reduction in biodiversity and to the use of agrochemical techniques that lead to pollution and the destruction of the ecosystem. It is also against the displacement of small farmers in favor of more capitalized ones (Martínez, 2004).

The aim of agroecology as a science is to seek effective technical and social solutions to favour the development of the most disadvantaged sectors in both underdeveloped and wealthier countries, based on a series of principles applicable to all farms, but fundamentally to those that are most affected by the use of technologies that are harmful to the environment. These principles are considered essential to achieve equitable, healthy, sustainable and highly productive systems (Martínez, 2004). In order to explore them in greater depth, we will start from the study prepared by the CIDSE Agroecology Task Force (2018), which defines them as a series of guidelines that establish the foundations on which agroecology is based, and distinguishes four basic dimensions: environmental, social and cultural, ecological and political.

With respect to the first of these, agroecology, through this dimension, favors the construction of more complex agroecosystems through the application of principles that tend to imitate natural ecosystems. Principles found in this area include:

- Agroecology involves positive interaction, synergy, integration and complementarity between the different components of agricultural ecosystems and elements of food systems.
- Agroecology promotes the creation and preservation of life in the field by providing conditions that favor plant growth.
- Agroecology recycles nutrients and biomasses from agricultural and food systems, optimizing and closing resource loops.

- Agroecology favors the optimization and maintenance of biodiversity with a wide variety of species both above and below ground over space and time.
- Agroecology eradicates the use of external synthetic inputs, helping pests, weeds and fertility to be controlled and improved through ecological management.
- Agroecology promotes climate adaptation and resilience and contributes to eliminating or reducing harmful greenhouse gas emissions by reducing the use of fossil fuels and increasing carbon sequestration on the planet.

In terms of the social and cultural perspective, the following principles should be mentioned:

- Agroecology is established on the basis of the culture, identity and tradition of local communities, as well as on their innovation and knowledge.
- Agroecology favors the development of healthy and varied diets, both seasonally and culturally appropriate.
- Agroecology favors horizontal contacts between farmers because it is knowledge-intensive. This contributes to the transfer of knowledge and skills and the creation of partnerships in which the role of the researcher and the farmer are balanced.
- Agroecology offers opportunities and encourages solidarity and debate between citizens belonging to different cultures or ethnic groups, as well as between urban and rural populations.
- Agroecology considers gender, racial, sexual and religious diversity, and fosters opportunities for youth and women, respecting and alienating gender equality and women's leadership.
- Agroecology is based on producer-consumer relationships and trust-based transactions and does not require costly external certification. Thus, alternatives to certification such as PGS (Participatory Guarantee Systems) or CSA (Community Supported Agriculture) are promoted.
- Agroecology promotes the maintenance of people's and communities' spiritual and material relationships with the land and the environment.

The third dimension, ecological, encompasses the following principles:

- Agroecology relies on small-scale distribution networks in contrast to linear distribution chains. In addition, it encourages the building of a network of transparent relationships between producers and consumers.
- Agroecology contributes to the provision of livelihoods for farming families, promotes the creation of markets and helps to build more sustainable local economies and jobs.
- Agroecology is based on the social and solidarity economy.
- Agroecology, through diversification of farm incomes, helps farmers become more financially interdependent, increases resilience as production resources and livelihoods multiply, promoting less dependence on external inputs and reducing crop failure through its diversified system.
- Agroecology empowers food producers to sell their produce at fairer prices and to respond to local market demand, thus harnessing the power of local markets.

– Agroecology reduces the need for aid and increases community autonomy by enhancing dignity and livelihoods.

Finally, in terms of the political dimension, the principles are as follows:

– Agroecology establishes a hierarchy of needs and interests of small-scale food producers who contribute to the supply of most of the world's food, not focusing so much on the interests of those large agricultural and food industry systems.
– Agroecology states that those who are part of the food system will be those who are in control of "seed, biodiversity, land and territories, water, knowledge and the commons", as this leads to better management of resources.
– Agroecology has the power to change hierarchical relations, as it favors increased participation of food producers and consumers in decision-making about food systems and considers new governance structures.
– Agroecology requires a range of complementary public policies, legislators and institutions, and levels of public investment to support its objectives in order to reach its full potential.
– Agroecology promotes diverse forms of social organization that are considered necessary for decentralized governance and more flexible local management of the food and agricultural system. It also favors self-organization and collective management of groups and networks from the local to the global level.

Each of the aforementioned agroecological principles corresponds to at least one of Food and Agriculture Organization (FAO)'s ten elements (Wezel et al., 2020), which emerged in order to achieve many of the Sustainable Development Goals (SDGs). According to (FAO, 2022), these elements include, on the one hand, "diversity, synergies, efficiency, resilience, recycling and co-creation and knowledge sharing" aimed at describing the common characteristics of agroecological systems, basic practices and innovation criteria. On the other hand, there are "human and social values and food culture and traditions", which focus on contextual aspects, and finally there are the elements of "circular and solidarity economy and responsible governance, based on the enabling environment.

These ten elements are highly interdependent and interrelated, and serve as a tool for countries to implement agroecology, since, thanks to their ability to determine the fundamental properties of agroecological systems, they guide policy making, as well as the planning, management and subsequent evaluation of the transition to agroecology.

With the current food, fuel and climate crises, the relevance of the social and ecological services provided by agroecology is more important than ever. According to Martínez (2004), agroecological schemes greatly benefit local populations, as the quality of food production is notably increased, and the system has been improved and regenerated, being used with a higher level of efficiency.

In short, it can be said that agroecology has a series of advantages over the methodologies used in the Green Revolution. These include the generation of a new agricultural technology that is based on low inputs and increases the degree of popular participation, the development of a new approach to agricultural development that

is much more sensitive to local agriculture, combining modern science with traditional knowledge, the use of ecologically sound methods that are not harmful to the ecosystem, and the fact that it is economically viable because production costs are minimized and available resources are used much more efficiently, among others.

However, although it is true that there is growing evidence of the beneficial contributions of agroecology, this discipline is not expanding rapidly. One of the obstacles to its full development is based on the need for specificity in the application of its techniques, since agroecological systems are not applied homogeneously, but require that each principle be adapted individually for each agroecosystem. For this reason, more diversified information is required regarding ecology, as well as social and agricultural sciences at a global level. For this reason, the agronomic curricula of a large number of agricultural universities are including aspects of agroecology and sustainability (Altieri, 2002).

On the other hand, the right level of political support is required for sustainable agricultural systems, because, although they are economically, environmentally and socially sustainable, without such support it will not be possible to take advantage of their full potential. Therefore, a series of institutional and policy changes are highly necessary to contribute to this end, either through increased public investment in agroecological methodologies or in the improvement of poor and marginal areas, or through the creation of equitable market opportunities for small farmers, among others.

2.2 Innovation in Education: Service-Learning

In the twenty-first century, higher education institutions are increasingly demanding community engagement, favoring the relevance of the academy in the civic life of citizens and emphasizing the debates about the role of the academy in this area (Felten & Clayton, 2011). In this context, Service-Learning (SL) constitutes an essential component, representing a comprehensive system that promotes critical citizenship while fostering emotional and social competencies.

SL is not specifically associated with an academic discipline, but is used generically in the field of education and in various contexts in a multidisciplinary manner. However, according to Deeley (2016), despite being a term used in a wide variety of disciplinary contexts, SL is fundamentally sheltered in the field of public policies for citizenship education.

Although originating from the United States, in recent years the SL system is expanding globally to other countries. However, despite its increased popularity, SL is not often studied as a unique style, as the existence of other more commonly known programs overshadows its prominence (Sigmon, 1979). However, while these last focus more on the learners own individual development, SL also embraces as one of its main dimensions the service offered to others. Therefore, it is erroneous to associate this discipline with those based on an individualistic perspective, since doing so would be offering a partial understanding of it.

In the academic literature, there are numerous definitions of the term SL, and it is therefore extremely difficult to find a single clarification that reflects the different points of view presented. However, the consideration of SL as a generic term makes the existence of broad definitions that capture its fundamental meaning as a particular mode of learning even more appropriate than specific definitions that may even be considered restrictive. Thus, a general framework of what SL is was provided by Felten and Clayton (2011), defining it as the many pedagogies that combine academic study with service provided to the community, both concepts being mutually reinforcing.

Another generic definition is that of Morgan and Streb (2001, p. 158), who define it as "*(…) a method of experiential education in which students apply what they learn in the classroom to real-world situations by performing community service. It aims to promote civic and citizenship education, as well as to provide a concrete learning experience to the subject matter studied in class*".

Folgueiras et al. (2013) define SL as a pedagogical methodology that encourages students to actively participate in community service, fostering their learning and allowing students to adapt to a reality different from that experienced in the classroom. Thus, this author, as well as Deeley (2016) defend that the elementary characteristics of SL are curricular learning and community service or civic engagement of the student. Thus, according to Folgueiras and Luna (2012), Stanford University represents both essential elements, as well as the existing relationships between them through the "Service-Learning Quadrants", which are: (I) Volunteering, (II) Practices and field work, (III) Community service/Non-systematic initiatives, (IV) Service-Learning.

The fourth quadrant is the one in which SL is placed, which considers both the development of projects and the participation of students in the identification of problems and in the formulation, monitoring and evaluation of plans (Folgueiras & Luna, 2012). Thus, through the development of varied projects it is manifested that solidarity service is equally relevant as the curricular objectives acquired (Folgueiras et al., 2013).

Therefore, although there are various definitions of what SL is, in general terms, a series of characteristics common to each of them could be determined, since they coincide in that SL experiences require, for the proper achievement of their objectives, the need for mutual collaboration between students and faculty and staff, as well as between members of the community and educational institutions (Felten & Clayton, 2011).

In this regard, four main elements that define SLcan be identified. The first of these refers to the nature of SL, identifying it primarily as a pedagogical model, although it has attributes of development, leadership or social responsibility models (Parker-Gwin & Mabry, 1998). Secondly, there is an equally relevant bidirectional relationship: practical learning should reinforce academic knowledge and academic training reverts to social service (Bessen, 2015). Consequently, SL involves students' volunteering in the community and their commitment to the activity itself, which, in turn, must be linked to the academic component of the course (Deeley, 2016).

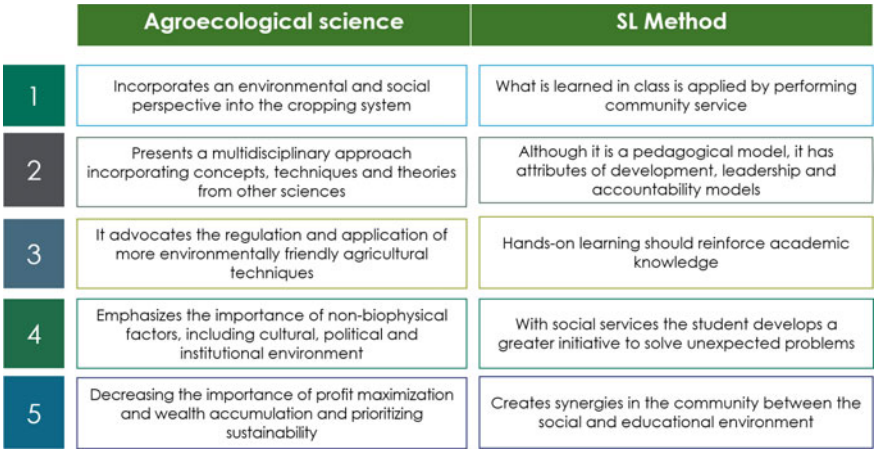

Fig. 1 Main methodological contributions of the agronomic and service-learning approach. *Source* Own elaboration

This premise highlights the necessary cooperation between educational and socioeconomic entities and the obligation to assume collaborative roles on the part of the different agents in a community for the creation of educational synergies. Thirdly, two mutually enriching types of learning must be combined: academic and practical (derived from experience). Finally, the choice of community service must obey pragmatic criteria, where the suitability of the service must reconcile the knowledge acquired (Fig. 1) (Howard, 1998). In reference to this last characteristic, Tapias (2001) states that "the action of service does not have to be a solidary or well-intentioned addition at the end or beginning of a learning process, but, closely linked to it, both gain from it".

Another key element of this discipline is related to the control of what is learned. Traditionally, the pedagogical curriculum defined what knowledge was to be instilled in the learner (Chen et al., 2016). The limited environment in which they were transmitted favored greater control over the subjects to be taught. However, in SL experiences, the communal nature of the service deductively guides learning. Students may encounter unexpected situations, which will allow them to develop greater initiative to solve real-world problems with theoretical teachings (Howard, 1993).

On the other hand, the role played by students in carrying out activities linked to SL is remarkable. This is mainly due to the fact that the attitude favored by lectures is the passivity of the student, where the creation of academic material or the practical application of knowledge is minimal (Michel et al., 2009), while SL encourages an active learning posture (Howard, 1993; Richmond, 2007).

With respect to the latter, Speck (2001) mentions the aspects of separation and that of integration and engagement. In relation to the first, the areas that comprise higher education (research, teaching and service) are not related to each other, and therefore students are being marginalized from public life, deprived of participating in it and of acquiring the knowledge and skills necessary for it. Secondly, the concept

of integration and engagement refers precisely to the capacity of SL as an escape route from this situation of separation, fostering greater integration than traditional education. SL integrates the three areas of higher education mentioned above and combines the work done in the classroom with the work developed in the community, preparing students to face public life and providing them with the necessary knowledge and skills to do so.

However, in order to establish a correct understanding of what SL entails, it is useful to study the principles that define it. On the one hand, according to Honnett and Poulsen (1989), in order to ensure the creation and maintenance of sustainable, high-quality service and that individuals appreciate service as a significant part of their lives, it is strictly necessary to combine service for the common good with reflective learning. Therefore, ten principles are established to guide those who apply SL, which are mentioned below:

1. An effective SL program should involve people in the development of responsible actions and ambitions for the common good.
2. An effective SL program should provide opportunities for people to critically reflect on their service experience.
3. An effective SL program should establish concise service and learning objectives for all parties involved in the process.
4. An effective SL program should facilitate the definition of the needs of those who have them.
5. An effective SL program clearly establishes the corresponding responsibilities of each person or organization involved in the process.
6. An effective SL program shares service needs with service providers through a process that takes into consideration changing circumstances.
7. An effective SL program assumes an active, genuine and sustained commitment on the part of the organizations.
8. An effective SL program, in order to meet its objectives, takes into account training, recognition and support, as well as supervision, monitoring and evaluation.
9. An effective SL program ensures an adequate and flexible commitment of time for service and learning that is beneficial to all parties involved.
10. An effective SL program is committed to fostering appropriate participation by and with diverse populations.

In addition, Sigmon (1979) offers a different perspective and presents three fundamental principles that emphasize community empowerment, which are the following ones:

1. The recipients of the service provided are the ones in charge of controlling such service(s).
2. The recipients of the service become more capable of serving and, at the same time, being served by their own actions.
3. Those who serve learn and have control over that which is expected to be learned.

In this context, it is possible to assume that SL favors positive social change. Thus, Batlle (2020) refers to the fact that it is not incompatible to achieve academic success and develop social commitment, and that it is beneficial to consider both aspects together. As stipulated above, the two fundamental elements of SL are curricular learning and civic service, so the combination of both will contribute positively to face the adversities present in contemporary society. This is due to the role of education in fostering political and social change, which makes SL fundamental to "revitalize education for citizenship and citizenship itself" (Mendel-Reyes, 1998, p. 32). SL, therefore, generates a virtuous circle (Batlle, 2020), bringing quality to the service provided through learning and, in turn, learning acquires meaning through the services provided. Thus, its influence on the achievement of social transformation objectives becomes relevant.

Taking into account all of the above, it seems evident that the SL methodology is a pedagogical tool whose results are enormously favorable. According to Deeley (2016), numerous authors confirm that SL not only brings a more refined sense of citizenship, but also contributes to higher student achievement through experiential learning. However, this author categorizes the most relevant effects of this discipline into three fundamental groups, which can be summarized as an improved sense of citizenship, accelerated intellectual development and the promotion of personal development.

Notwithstanding, according to Felten and Clayton (2011), SL offers more favorable educational outcomes under specific conditions. First, the learning and service objectives must be integrated and appropriate. Second, the student's work must be developed taking into account the alignment and complementarity of objectives with community and classroom experiences, reflective activities, and assessment. Third, the partnership with the community must be collaborative throughout the process. Fourth, the experience should integrate the activities carried out by students both inside and outside the classroom, as well as the knowledge and perspectives of all participants in the experience. Finally, the pedagogy, while intentionally designed, must be flexible enough to allow it to adapt to dynamic situations on the one hand, and to meet the opportunities and needs for skill development of each of the participants on the other.

On the other hand, from a critical point of view, Speck (2001) presents three objections to SL. On the one hand, SL can be seen as time-consuming and time-consuming to study academic content and requires many resources that, if not used for this purpose, could be put to other uses. Secondly, it is ironic that an activity that is intended to foster a desire for lasting volunteerism should be required. In this sense, the compulsory nature of SL is a drawback to the proper use of the volunteer activity, which would benefit more from an environment in which service is naturally part of a person's civic responsibility. Finally, SL may even come to be seen as a form of indoctrination, at least, from a civic point of view. Furthermore, Deeley (2016) also suggests that studies by Jones (2002) and Jones et al. (2005) find that there are a number of learners who do not benefit from the potential advantages that

SL can bring them, which may be due in part to students' cognitive limitations in linking concepts learned in the classroom to situations experienced in life outside the classroom.

2.3 Synergies Between Agroecological Science and the ApS

The EHEA has transformed the university methodology by involving a greater number of agents and promoting competency-based learning (Cazorla-Montero et al., 2019). These are a complex concept that go beyond theoretical knowledge, including ethical values, practical skills, motivation, attitudes, emotions and other social components that are not mutually exclusive and that act together to effectively achieve a common goal (Hersh et al., 1999). Not only the pedagogical content has been transformed in the university system, but also the role assumed by the institution itself in society (Trow, 2007; Välimaa & Hoffman, 2008). It is no longer conceived as a passive actor, as a simple transmitter of knowledge. It is now presumed that it must exert the necessary impetus to collaborate in social progress.

The EHEA innovates pedagogically seeking to transmit values and competencies through higher education, where sustainable development and care for the environment have a place (Albareda-Tiana et al., 2018; Molderez & Fonseca, 2018). For this task, the service-learning method is defined as a good way to transmit the agronomic approach thanks to the characteristics as shown in Fig. 1 and detailed below:

- Service-learning fosters ecological learning through projects on real agricultural needs: Students can apply their previously acquired knowledge of environmental analysis to a real environment. In many cases the students are familiar with the field, which is beneficial, as this feature helps the participants to identify the problems of the field more diligently.
- The environmental experiences of ApS are susceptible to be applied in diverse temporal and educational scenarios: the vision of respect and social solidarity towards ecological spaces are not only restricted to higher education, although they are encouraged from this area. The only difference that will exist between them will be the different level of deepening in the teachings on sustainable environmental development, which will be adapted to the characteristics of the target public. They can be transferred to formal and non-formal educational levels in a wide range of ages.
- Creation of links between educational institutions and the community to constitute a sustainable agrarian productive system: the service performed has the function of culturally and ecologically approaching the processes of accelerated degradation existing in the countryside and seeking solid alternatives that transform social organization and technological use into sustainable instruments for the appropriation of nature (Barth et al., 2014).
- The realization of the service-learning method involves the acquisition of knowledge and practical methods for agroecological production: The planning of an

ApS experience includes a prior analytical effort through which to learn about the different environmental aspects. In order to evaluate the different degrees of sustainability and propose alternatives to initiate reconversion, students will actively apply the formal knowledge acquired to understand complex ecological relationships. Furthermore, in this learning process, transversal competencies derived from the interaction with the cultural, social and ecological environment are developed (Clifford, 2017).

- ApS promotes cooperation between entities from different areas: there is an equally relevant bidirectional relationship between educational, cultural, political and social organizations. Practical learning should reinforce academic knowledge, and academic training is reflected in social service. This premise highlights the necessary cooperation between educational and socio-economic entities and the obligation to assume collaborative roles by the different agents of a community for the creation of synergies, building sustainable agroecological systems.

3 Case Study

In 2019, the Spanish university network consisted of 83 universities, 50 of which were public and the remaining 33 were private (Ministerio de Universidades, 2020). The establishment of democracy in Spain in 1975, and the subsequent granting of administrative and legal powers to the 17 regions that make up the country in 1985, leads to a significant increase in the number of universities. While in 1975 there were only 28 universities, by 1985 seven more had been founded and, 44 years later, the number of universities had tripled (Ministerio de Ciencia e innovación, 2008). These data reflect the progressive increase of private universities in the higher education scenario. While the number of public universities has remained constant since 2009, six new private universities have been created (Ministerio de Universidades, 2020).

The regulatory framework of higher education in Spain played a major role in the changes in the university context. Prior to the 1970s, the institutional framework that regulated university organization was based exclusively on state-approved norms and laws. The establishment of democracy in 1975 represented a turning point in the administration and social mission of the university. After a comprehensive reform, the University Reform Act (LRU) was passed in 1983, which sought to create stronger ties between the university and society by promoting, among other things, opportunities for access to the university for all social strata (Vidal, 2003).

In 2001, a new regulatory change took place with the approval of the New University Act (LOU), which aimed to regulate the role of higher education in a more internationalized and multidisciplinary context. In this way, the power of the central government was strengthened, and it became the coordinator of the university environment in Spain. For this purpose, among other changes, the National Agency for Quality Assessment and Accreditation of Spain (ANECA) was created, which would act as an independent arbiter to safeguard the quality of the university system. These changes were aimed at converging with the European Higher Education Area

(EHEA), which would promote the modification of the University Act (LOMLOU) in 2007 (Montané et al., 2017).

The EHEA has replaced the traditional teaching process with a more dynamic one. While previously the role of teachers and students was very fixed and there were few forms of interaction between them, the new teaching model makes this relationship more dynamic (Rico, 2010). The teaching staff is no longer just a conduit of knowledge through the delivery of an expository class, but becomes a tutor, professional and academic. Guidance is a new task assumed by the teaching staff, to mark the path of teaching which, in this case, can reach the students through different channels (López-Pastor et al., 2013).

The master class, although still a recurrent element in Spanish university education, is no longer the fundamental axis of knowledge transmission. With the establishment of the EHEA, self-learning and autonomous work by students are essential in their education. In this case, we have moved from an academic model that centralized learning in the teaching staff to one that focuses learning on the student body. This model strengthens and creates social capital, since it promotes the transfer of knowledge, interaction with the environment and promotes the practical application of knowledge in both the public and private sectors. Social capital is claimed as shared knowledge, agreements, norms, rules, and expectations about interaction patterns of groups of individuals to carry out a recurrent activity. This type of capital refers to the set of interpersonal trust networks in human societies, networks that can be driven by norms of reciprocity and mutual aid and that have a strong relationship with social networks and participation in community associations (Ostrom, 1995).

Considering the beneficial characteristics that this type of capital has for society, many university initiatives have been designed to implement it directly or indirectly. Strengthening trust between agents of the same community, the promotion of commitment and civic values leads to the creation of social capital and, these values are also contemplated in the new higher education of the EHEA. One of the teaching methodologies that best engages students in this process is the Service-Learning experience, making this educational method ideal for promoting social cohesion.

With the application of SL, students, by working on real problems of the environment, promote cooperative contents and competencies that strengthen community ties while assimilating theoretical knowledge. Furthermore, this pedagogical experience not only strengthens relationships with the individuals involved, but also acts in a double direction: the corporate image of the educational organizations that promote these experiences is strengthened. This fact ensures that educational action is promoted in the social sphere, creating collaborations between various social entities, and facilitating the dissemination of pedagogical ideas and values, which in turn feeds back into social capital.

In Spain, SL is a methodology that has gradually established itself in various areas of knowledge (Engineering, Economics, Law and Medicine). Its presence has intensified over the last decade, although it has been implemented for the first time in Spanish higher education for more than 20 years. In 2010, the SL (U) Network was founded in Spain, an organization that promotes this methodology exclusively in the university environment. This initiative was promoted by the University of Barcelona

and in 2022, it has more than 40 Spanish universities associated with this project. In addition, in 2017 *the Asociación Red Universitaria de Aprendizaje-Servicio—ApS (U)* was constituted, which increases the degree of collaboration between the institutions that implement this methodology.

Agriculture is one of the sectors in which SL has been implemented. In fact, the implementation of this methodology has been carried out from an environmentally friendly and innovative approach, such as agroecology. In Spain there are several masters' degrees in public universities that use this approach to improve agricultural management from the ecological-productive, socioeconomic and political-cultural dimensions. One of these masters uses SL in its graduate teaching methodology in agroecology. Table 1 lists the companies participating in this consolidated SL program.

In this case study we have analyzed the impact of participating in an SL experience for the management of the company, which develops its activity in the agricultural sector. In this way, through the application of the balanced scorecard methodology, the most important objectives of the company are evaluated in terms of the success factors derived from the experience, as well as the indicators that identify whether or not the objectives established for university-business collaboration are met. The data used to create the balanced scorecard come from surveys carried out by the company.

4 Methodology

The Balanced Scorecard (SBSC) is a method for business management that provides information on the status of the strategic plan of a company and its employees at the level of results. This method also identifies possible deviations from the above-mentioned plan and enables the necessary decisions to be made in order to focus on the goals.

The concept of the balanced scorecard was developed in the early 1990s as an improvement to the widespread business valuation by managers based solely on the financial perspective. In this way, the balanced scorecard supports the importance of the intangible assets of a company in establishing competitive advantages and goes on to value the activities of a company in terms of its focus and strategy, providing managers with a global view of business performance. This method requires that the organization be evaluated from four standpoints:

1. Business growth and learning
2. Internal processes
3. Customers
4. Finance

Figure 2 shows the link between the company's business vision and the key factor indicators, converting the organizational strategy into specific objectives.

Prior to the design of the balanced scorecard, the organization must have a strategic plan to be implemented with the help of the SBSC.

Table 1 Description of the companies participating in the agroecology master internship program

Company	Location	Spanish region	Legal form	CNAE Code 2009 primary	Company's foundation
Company 1	Santa Cruz de Tenerife	Canary Islands	Cooperative	Wholesale trade of fruits and vegetables	22/01/1972
Company 2	San Pedro del Pinatar	Murcia	Other types not defined	Wholesale trade of fruits and vegetables	17/08/2007
Company 3	Lliça del Vall	Catalonia	Limited Liability Company	Non-specialized wholesale trade of food, beverages and tobacco products	16/07/1987
Company 4	Murcia	Murcia	Limited partnership	Processing of other food products	04/09/1992
Company 5	Suubirats	Catalonia	Limited partnership	Winemaking	17/12/2009
Company 6	Tiana	Catalonia	Limited partnership	Winemaking	12/01/2017
Company 7	Peralada	Catalonia	Limited partnership	Winemaking	09/07/2002
Company 8	Jumilla	Murcia	Cooperative	Manufacture of olive oil	21/09/1982
Company 9	Subirats	Catalonia	Limited partnership	Vine cultivation	14/06/2016
Company 10	Cornudella de Monstsant	Catalonia	Limited partnership	Pig farming	17/06/2015
Company 11	Alzira	Valencian Community	Cooperative	Citrus cultivation	01/01/1999
Company 12	El Vendrell	Catalonia	Limited partnership	Renting of real estate for own account	02/05/1987
Company 13	Cariñena	Aragon	Limited partnership	Electrical installations	02/10/2018

Source Own elaboration based on data from SABI (2021)

Fig. 2 Relationship between the vision and the indicators of a BSC. *Source* Own elaboration

In the planning of the SBSC design, the controller, which is usually the person in charge of it, will guide the managers in an initial process consisting of introduction, development, and conclusion, leading to a longer process that we will see reflected in the following stages:

1. *Step 1. Identification of the key success factors of the organization*: It is necessary to identify the key success factors at the organizational level based on the strategic plan, the mission and, of course, the corporate vision. To recognize these factors, it is important to perform a cause-effect analysis on different aspects of the organization such as, for example, the relationship between employee motivation and productivity. The balanced scorecard is usually performed by working on the factors "Customers, "Growth and learning", "Financial" and "Internal processes", which are the most relevant within the organization.
2. *Step 2. Design of a strategy map*: The strategy map allows us to identify the interrelationship between the key success factors seen in the previous stage, as well as the causal relationships established between these factors. As an example, we can state that investment in employee training favors an improvement in their skills, and therefore greater efficiency in performing their tasks. This greater efficiency, in turn, will lead to an improvement in customer satisfaction, which will supposedly result in an increase in profitability per customer, due to an increment in the purchase of products or services. This boost in turnover will ultimately lead to increased financial capacity, with an associated higher profitability.
3. *Step 3. Indicator selection*: Once the strategic map has been completed, a selection of the most appropriate indicators must be made to provide information on all the key success factors at the organizational level. For example, if we consider the introduction of new machinery as a key success factor, a possible indicator would be an analysis of costs in relation to the increase in production.
4. *Step 4. Composition of the SBSC*: The types of balanced scorecard can vary greatly, depending on the type of organization involved. In any case, there are a series of minimum elements: the four key success factors, the objectives, the indicators of their evolution and goals for each indicator.
5. *Step 5: Communication to the organization*: After deciding which indicators will be measured, how they will be analyzed and the frequency with which the process will be carried out, the entire organization must be informed of the implementation of this management tool.

   Communication to the organization is a vital aspect for the positive evolution of the SBSC due to the importance of spreading knowledge of the SBSC among as many employees as possible, so that they can work together to achieve the objectives associated with the indicators, as well as providing information.

   The employee in direct contact with the SBSC must follow a series of standardized processes in terms of data processing, as well as internal reporting, etc. In this regard, many organizations have integrated real-time data on key success factor markers on their intranet.
6. *Step 6. Monitoring of the SBSC*: The monitoring of the balanced scorecard will vary depending on the size of the organization, in the case of small companies the

manager or other person in charge will be responsible for the monitoring tasks. This changes for medium or large companies in which there will be the figure of the controller who will oversee monitoring and providing information to the responsible managers.

In these companies where there is a controller for reasons of size, it is important that there is direct communication between them and the managers to effectively monitor the SBSC and adjust when necessary, so that the tool will be fulfilling its mission.

5 Results

The following is the company's strategic map, focused on the SL experience, which specifies the areas, perspectives, and strategies to be evaluated (Table 2).

Once the strategic map of the company is established, the next step is to select the indicators. There are two types of indicators, inducers and results indicators. Inducers evaluate the actions that are carried out to achieve the objective set, while outcome indicators evaluate the extent to which these objectives have been achieved. Both are related, since thanks to the inducers we can anticipate the achievement or not of the outcome indicators.

There are two types of perspectives, external or outcome perspectives and internal or facilitating perspectives. The external perspectives refer to the intangible assets of the company, while the internal perspectives take care of those objectives over which the company still has some freedom of action, in addition to facilitating the achievement of the objectives of the external perspectives. There are four ways of choosing the indicators to be included in the SBSC, these are:

1. *Indicators from the perspective of employee learning and growth*: This first perspective focuses on assessing and increasing the degree of motivation and development of the team, since these are fundamental elements for obtaining the proposed results. As we find ourselves more and more in a constantly changing environment, it is essential to continuously acquire new resources to train people properly.
2. *Indicators from the perspective of internal processes*: Internal process indicators are essential for the proper performance of the activity of the company, so proceeding in one way or another, will cause some results or others. In each department the indicators will be different and will be subject to each type of activity and will have to be subordinated by the person in charge of that department.
3. *Indicators from the customer perspective*: We must identify the customer segments in which the company is competing, since they represent the sources of income that we have as a financial objective. For this reason, we need indicators that show us elements such as customer satisfaction, customer loyalty or whether they recommend the company to others.

Table 2 Strategic map of the company

Strategic map of the agro-ecological enterprise			
Strategic objective	Strategy to follow	Area	Perspective
Customer-focused approach	Evaluation of consumer satisfaction with the SL experience	Commercial/sales	Customers
	Establishment of standards and rules of service with SL experience		
	Investment in experience innovation SL		
Increased sales revenue from SL experience	Contribute to building a loyal customer base	Commercial/sales	Customers/financial
	Include corporate image positioning in work/sales plans		
Professional development and motivation to improve productivity through the SL experience	Analyze the company's performance on a regular basis	Human Resources	Growth and learning
	Reducing turnover while maintaining a good level of motivation		
Budgetary cost management for consistent use of financial resources in the SL experience	To create a costing system to improve its management and to obtain ideal margins	Accounting and finance	Financial
	To develop budget management and control of expenditures and investments		
Obtain financing for the realization of the SL experience	To develop a plan to improve relations with financial institutions	Accounting and finance	Financial
	Reducing risk by studying the current situation with customers		
Standardize logistics processes and improve service to customers	Determine the processes to contribute to the quality, effectiveness and efficiency of the service performed during the SL Experience'	Logistics	Internal processes

Source Own elaboration

4. *Indicators from the financial perspective*: Within this perspective we include the need to satisfy shareholders, to focus the indicators and objectives for the other perspectives. Since all the previous ones end in a financial goal, or what is the same, with an economic result, we include the need to satisfy the shareholders, in order to focus the indicators and objectives for the other perspectives.

Consequently, the four perspectives are interrelated, since the behavior of one of them can interfere with another and change the results. To obtain an overall view, quantitative and qualitative variables must be analyzed from the point of view of the four perspectives (Table 3).

Once the indicators used in this case study had been defined, the data needed to analyze the SL experience in agroecology were collected. Through the surveys carried out in the company, it was possible to draw up Table 4, which incorporates inducer and result indicators to determine whether the SL experience has met the expectations of the company's managers.

The figures of the results indicators are heterogeneous. Considering the financial factor, it can be observed that the economic profitability is higher than the financial profitability, exceeding the established target. Consequently, the magnitude of the interest, taxes and financial expenses of the company has led to a negative financial result. On the other hand, the resulting "Sales growth" indicator has almost doubled the established target. However, the "Customer attrition rate" indicator is lower than expected and smaller than sales growth, which indicates that the sales per customer ratio has increased during the SL experience.

Regarding the customer perspective, the results achieved were the best among the four factors studied. Both the "Index of new customers" and the "Customer retention rate" exceeded the figures for the inducer indicator. In addition, it is necessary to highlight the good result of the "Customer satisfaction index", which exceeds the goals established for the SL experience by more than 12 percentage points. Among the results of the consumer factor indicators, the one with the worst performance is the "New customer revenue rate", since the proportion of sales corresponding to new customers of the SL experience is slightly below the level established by the inducer indicator.

The only indicator for the Internal Processes factor, focused on the reduction of claims, had not performed well, since it exceeded the expected claims. This is not the only indicator that shows the degree of satisfaction with the application of this methodology in which the result indicators have not evolved as positively as expected following the marks set by the inducer indicators. Both the "Satisfaction in the work environment" and the "Gallup Index" have not reached the expected objectives, a situation reproduced in all the indicators of the "Growth and learning" factor. Possibly the involvement of workers in the SL methodology was not as high as expected, since the number of suggestions and training hours did not exceed 60% of the figure stipulated by the inducer indicator.

Table 3 Indicators used for the elaboration of the SBSC

Indicators					
Perspective	Variable	No	Indicator	Formula	Description
Financial	Efficiency	1	Economic profitability	$\frac{\text{Earnings before interest and taxes}}{\text{Total assets}}$	Determine whether the results obtained through SL experience are consistent with the capital employed
		2	Financial profitability	$\frac{\text{Net income}}{\text{Shareholder's equity}}$	Determines the return obtained through the SL experience based on the funds contributed by the partners
	Performance	3	Sales growth	$\frac{\text{sales} - \text{sales}_{-1}}{\text{sales}_{-1}}$	Determine whether the results obtained through SL experience are consistent with the capital employed
		4	Customer attrition rate	$\frac{\text{customers} - \text{customers}_{-1}}{\text{customers}_{-1}}$	Determines the return obtained through the SL experience based on the funds contributed by the partners
Customers	Satisfaction	5	Customer satisfaction index	It is determined through a quarterly survey trying to evaluate the price, quality, image, trust and added value of the SL experience	

(continued)

Table 3 (continued)

Indicators					
Perspective	Variable	No	Indicator	Formula	Description
	Volume	6	Index of new customers	$\frac{\text{New customers}}{\text{Total customers}}$	Determines the ratio of new SL experience customers to existing customers
		7	New customer revenue rate	$\frac{\text{Sales due to new customers}}{\text{Total sales}}$	Determine the proportion of sales corresponding to new customers of the SL experience
	Loyalty	8	Customer retention rate	$\frac{\text{No. customers at end of the period.} - \text{No. customers acquired during the period}}{\text{No. customers at the start of the period}}$	Determines the company's ability to retain SL experience customers
Internal processes	Complaints	9	Complaints	$\sum$ Claims	Determine the total number of complaints made during the SL experience period
Growth and learning	Quality in the work environment	10	Satisfaction in the work environment	$\frac{\text{Satisfied employees}}{\text{Total employees}}$	It is determined by a work climate study conducted through an anonymous survey, which includes the satisfaction of long-term employees with the SL experience
	Training and retention of personnel	11	Training hours	$\sum$ Training hours	Determine the monthly hours spent by employees in training students of the SL experience

(continued)

Table 3 (continued)

Indicators					
Perspective	Variable	No	Indicator	Formula	Description
	Performance and compliance	12	Salary expense to sales ratio	$\frac{\text{Salary cost}}{\text{Sales}}$	Determines the proportion of income allocated to the remuneration of employees who train the students of the SL experience
	Motivation and delegation of power	13	Employee suggestions	$\sum$ suggestions	Determine the suggestions that have been provided by employees in relation to the SL experience
		14	Gallup Index	It is based on a survey that determines the level of employee commitment to the SL experience through the development of twelve questions	

Source Own elaboration

Table 4 Elaboration of the SBSC

Indicators						
Perspective	Variable	No	Indicator	Frequency	Result	Goal
Financial	Efficiency	1	Economic profitability	Monthly	0.68%	>0
		2	Financial profitability	Monthly	−0.17%	>0%
	Performance	3	Sales growth	Monthly	9.32%	>5%
		4	Customer attrition rate	Monthly	8.64%	>10%
Customers	Satisfaction	5	Customer satisfaction index	Quarterly	87.80%	75%
	Volume	6	Index of new customers	Monthly	16.20%	15%
		7	New customer revenue rate	Monthly	19.34%	20%
	Loyalty	8	Customer retention rate	Monthly	79.40%	75%
Internal processes	Complaints	9	Complaints	Monthly	3	1
Growth and learning	Quality in the work environment	10	Satisfaction in the work environment	Monthly	79.51%	90%
	Training and retention of personnel	11	Training hours	Monthly	5	10
	Performance and compliance	12	Salary expense to sales ratio	Monthly	0.36%	0.50%
	Motivation and delegation of power	13	Employee suggestions	Monthly	6	10
		14	Gallup Index	Monthly	79.12%	80%

Source Own elaboration

6 Conclusions

The current educational context has transformed the university methodology, involving a greater number of agents and promoting competency-based learning. Competencies are a complex concept that goes beyond theoretical knowledge, including ethical values, practical skills, motivation, attitudes, emotions and other social components that are not mutually exclusive and that act together to effectively achieve a common goal (Hersh et al., 1999).

If the change in the role of university institutions has been protracted, the change in agricultural production has been no less so. New techniques and the increase in demand have implemented an intensive production system whose objective is to

maximize productivity. In most of the processes, the inputs used are not adequate, producing negative impacts on the environment. In order to avoid this degradation, it is necessary to understand the particularities of agricultural science as a different ecosystem. Therefore, in order to analyze ecological systems we have to understand and analyze their complexity, not reject it. To this end, we will apply scientific knowledge from different disciplines: anthropology, biology, ecology, economics, environment, science, geography. Having established the tools of analysis and the framework of study, we conclude that agriculture is not only composed of biological variables; social and cultural particularities decisively affect the environment. These fundamentals are included in agroecology, a more socially sensitive ecological science. This perspective calls for new methods and more involvement of the agents to preserve biodiversity, the ecological processes of each area and prevent the collapse of the agricultural market.

Therefore, the SL method is an instrument that provides an opportunity to reconsider the role of education in ecosystem conservation. The objective is to enhance the social responsibility of these institutions and not to be mere channeling of academic and scientific merit for profitable professional careers at the individual level (Boyer, 1994). SL could be defined as a revulsive of traditional pedagogy with which it presents several notorious differences. One of them is related to the above-mentioned conflict of objectives. While SL promotes civic involvement and promotes student involvement with a holistic vision of teaching, classical pedagogy obeys educational reductionism, where individualistic advancement represents the objective of this procedure. The quote "The competitive individualism of the classroom (…) reflects a pedagogy that emphasized the individual as the primary agent of knowledge" (Palmer, 1990), reflects the clear disjunction between one method and the other, while individual responsibility is promoted by traditional classes, SL promotes social responsibility (Howard, 1993).

All these nuances make SL an ideal methodology for involving educational institutions and social entities in the fight against environmental problems. The degree of involvement and autonomy achieved in the SL experiences promotes a greater sense of citizen responsibility. The participants involved in the experiences become involved in the cause, studying its origins, analyzing the derived problems, and searching for possible solutions. This shows that the correct involvement of students creates positive externalities in their environment, which feedback on each other. The conviction that SL is a good strategy to involve students in the analysis and resolution of ecological problems, leads us to propose it as an effective tool to alleviate the promotion of agroecology.

This chapter has analyzed the management and results of an agroecological SL experience linked to the higher education environment. In order to know the results of this experience in detail, and its scope, we have chosen to implement the Balanced Scorecard methodology. In this way, a detailed planning, control and communication process is established showing clearly the achievement of the previous objectives that the company had when it agreed to participate in the FS experience. The implementation of the Balanced Scorecard does not start when the SL experience begins, but the decision of which objectives to achieve, which tasks are to be performed at

all organizational levels of the company and how the responsibility for the achievements is distributed shows that the anticipation is as important as the holistic and heterogeneous way in which this methodology is implemented.

In the case study analyzed in this chapter, the performance indicators, although they have not reached the maximum level of expectations reflected by the inducer indicators, do show positive aspects of the application of the SL experience. The factor that has performed best has been the one related to consumers, their retention and the level of sales. The indicators show that, in many cases, the initial estimates have been exceeded, resulting in a positive economic profitability. However, the learning and growth factor was the worst performer. All the purely active initiatives that were demanded of the company's employees, such as the provision of training hours and the preparation of suggestions, had low quotas. As for the level of satisfaction, although it was not alarmingly poor, it also failed to meet expectations. This aspect needs to be reinforced in future SL experiences, should they be carried out again. Possibly the lack of communication about the need to implement the SL experience and the lack of feedback on the initiative have been key factors in the failure of the indicators for this factor.

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Conflicts of Interest
The authors declare that they have no conflicts of interest.

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Performance Appraisal Systems for the Evolution of Environmental Competencies: Achieving Goals and Rewards

Mariana Leitão B. Alves and Carolina Feliciana Machado

Abstract Performance management is a process that contributes to helping an organization's workers in improving their professional competencies. Therefore, performance measurement is directly connected with organization's people management. In this chapter, the issues related with the worker's environmental competencies are addressed, namely in what concerns the promotion of environmental behavior through performance measurement systems, in which there is a focus in the definition and accomplishment of objectives and rewards. The manager's role is of growing importance, namely in the way which they communicate with the workers, and in the information that they give to them about the company's strategy and its vision regarding its environmental impact.

Keywords Performance management · Goals · Rewards · Environmental competencies

1 Introduction

This chapter's main aim consists in a brief critical review of the existing literature on performance assessment systems for the evolution of environmental competencies, specifically with regard to the achievement of objectives and the attribution of rewards.

The choice of this theme rests on the specific interest in issues that have been increasingly talked about. In recent years, increasing attention has been paid to the environmental problems we face today, which tend to get worse in the future. Very recently, warnings given by the international community have become more and more frequent and alarming. Watts (2018) mentions the alarming deadline, set by

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the scientific community, that we have, so that it is still possible to reverse the negative impact caused by climate change, more specifically, twelve years. The twenty-first century has shown an interest in environmental concerns across the planet, regardless of the field of operation, be it politics, public domain or even business (Ahmad, 2015). Small individual changes will no longer be enough to change the state of the planet, requiring joint global action. This action includes all possible efforts and, in this way, also at the level of organizations. These therefore have a fundamental role, since they can no longer look only to economic issues as a means of differentiation. Thus, in their attempt to implement changes that cause less impact on the environment, they have to make changes at different levels. In this way, the human factor cannot be left out. Any practice implemented in organizations has an influence on their workers, reason why human resource management must also evolve according to the needs that are being created. In this way, the need to promote environmental behaviors arises with the addressed changes.

The problem that organizations face relates to how they can promote these behaviors. Thus, during the study of this topic, issues related to this problem are analyzed. In the following sections there is an attempt to answer questions such as "how can the adoption of environmental behaviors by employees be promoted through performance management?", "why is it necessary to promote such behaviors?", "how can do the rewards fit in promoting the adoption of environmental practices?", "how can a manager deal with the implementation of these practices?", among other questions. Finally, the answers found to these questions are critically analyzed, in the final remarks, as well as the limitations found in relation to them.

2 Conceptual Analysis

Performance evaluation systems make up one of the human resources management practices of an organization. According to Ahmad (2015), the performance management process contributes to helping the workers of an organization to improve their professional skills, and the recognition of the corporate strategy culminates in it. In addition, performance management consists of setting goals, monitoring behaviors and evaluating them so that, in the end, workers focus their work on ways to contribute to achieving the organization's goals (Zoogah, 2011). For a better understanding of the term, we consider it important to divide its components into "management" and "performance". So let's look at the following definitions: "Management (…) is the organ of society specifically charged with making resources productive, that is, with the responsibility for organized economic advance (…)" (Drucker, 2012a: 0.4); Kitana (2016, p. 21), by his turn, considers that "Management employs the science of planning, organizing, directing and monitoring, while creates the people mindset towards work as an art."

It is true that performance is difficult to define, as it is an ambiguous term and may include different components. Lebas (1995, p. 29) defines performance as "deploying

and managing well the components of the causal model(s) that lead to the timely attainment stated of objectives within specific constraints to the firm and to the situation."

Given these definitions, it appears that performance evaluation is directly associated with management in organizations, more specifically with people management, since it is necessary to organize and guide them, with planning that goes against the creation of objectives and their fulfillment within a specific time frame. Thus, it will be possible to measure the performance and evolution of employees. According to Otley (1999), there is no universally applicable performance control system. Therefore, the choice of appropriate performance management techniques depends on the circumstances in which the organization finds itself, assuming as main variables the objectives and strategy decided by the management.

3 "Pro-environmental" Behavior

The purpose of this study is the analysis of performance evaluation systems that promote the evolution of environmental competencies. For this to happen, these systems must be fully integrated into organizations' environmental policies. Firstly, it is not enough to have knowledge about relevant environmental issues, knowledge that can be acquired through training and development practices. These practices help to increase the environmental awareness of workers in relation to the general objectives of the organization, helping to create change in the corporate culture (Zoogah, 2011). In fact, some training programs exist as a result of performance assessment results, since certain training needs can be detected, in this case in the environmental area. There is a conceptual difference between being knowledgeable about environmental issues and adopting "pro-environmental" behavior. The latter is defined by Kollmuss and Agyeman (2002, p. 240) as "behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world". In view of this, it is important, secondly, to assess the reason for such a gap. According to the model of Kollmuss and Agyeman (2002), it is due to several barriers, such as, for example, existing values, lack of environmental awareness, lack of incentives, old behavior patterns, among others. Thus, it is important that the Human Resources Manager is able to find a way to counter these barriers, to promote desired behaviors. In addition, the adoption of previously unexecuted behaviors can become a difficult task, as it implies a change in behavioral habits. This change can be resisted by those who practice it, even if it brings advantages and is voluntary.

But why would an organization want to promote "pro-environmental" behavior? What advantages will the organization have in adopting such practices? Here, it is important to create a separation, for a better understanding of the topic. Firstly, relevance is created in the certification of companies through standardization. A standard is, according to Abbott and Snidal (2001, p. 345), "a guide for behavior and for judging behavior". Analyzing another definition, according to Guasch et al. (2007, p. 9), "a standard can be considered as a model or an example that has been established

by some form of authority, custom, or general consent. Standards define characteristics or performance, convey information, or provide a means of communication". In this way, in practice, they are documents adopted by organizations that give them specifications and guidelines, in order to ensure that everything that involves their action is adequate to their objectives. This has advantages and disadvantages. Still according to Guasch et al. (2007), the positive impact ranges from improvements in production efficiency, cost reduction, reduction of information errors, increased competitiveness, among others. While the negative impact can be seen in impediments to innovation, for example. These certifications are relevant for this study, since the International Organization for Standardization (ISO) created a specific standard for environmental management that, in addition to the advantages specified here, creates others for certified companies. Thus, and secondly, an analysis of this particular certification, ISO 14000, is in order. Aba and Badar (2013, p. 45) analyzed this standard in their study, saying that "ISO 14000 fosters principles and practices that are germane to the competitive advantage of sound environmental performance: resource allocation, responsibility and accountability, and continuous performance evaluation for improvement". So we come to the initial question. The adoption of this standard, with "pro-environmental" practices, will, according to Aba and Badar (2013), have benefits such as improving the organization's image in the market, thus attracting investors whose criteria are aligned with the mentioned practices, and satisfying environmental expectations of customers, in addition to simultaneously protecting human and environmental health.

4 Objectives and Rewards

As the central theme of this chapter refers, it focuses on meeting objectives and attributing rewards, so it is also vital to analyze the issue from this point of view. Rewards are a means of reinforcing workers' empowerment and decision-making, improving corrective and preventive measures that they initiate. In this way, they can be a reinforcement to continually motivate and increase the commitment of workers to be environmentally responsible (Daily & Huang, 2001). As we saw earlier, one of the barriers to the adoption of an environmentally friendly behavior, in this case, the adoption of environmental practices in an organizational context, is the lack of incentives. For this reason, rewards gain greater importance as a way of rewarding desired behaviors. In addition, rewards appear, according to Otley (1999), as one of the issues to be addressed when talking about organizational performance management, in the sense of compensating employees for achieving certain organizational performance goals. Likewise, the first step towards meeting objectives is defining them, so that they can be integrated into performance assessment parameters. These systems must, in addition to defining safety, legitimacy and justice objectives, provide feedback to workers and support their continuous development (Jackson et al., 2011). There are a wide variety of theories and techniques on how to increase the achievement of objectives while simultaneously reducing resource consumption. These go

through benchmarking, simultaneous engineering and cost target, for example, which involves the technical specification of what is intended to be achieved, in addition to being related to organizational behavior and motivation (Otley, 1999).

5 Performance Appraisal

A study by Ramus (2002) analyzed how managers could improve workers' adherence to their organization's environmental policies and practices, concluding that, in the first place, it is necessary for managers to communicate the company's commitment to the application of these practices. A good correspondence between the objectives dictated by the organization, its planning and, finally, its evaluation, dictates the result that the application of the organizational strategy will have. In addition, it was found that, with regard to environmental issues, managers attach less importance to environmental activities compared to other activities, so workers who saw greater support for environmental practices were more predisposed to apply them. Thus, with regard to performance assessment systems, setting goals and assigning rewards, it is essential to involve workers and recognize and support managers, as these practices, along with motivation, communication and people development are formal and classificatory categories, which will only gain meaning and become concrete with a manager's experience (Drucker, 2012b).

The financial performance measurement system becomes, in matters of gauging the Human Resources strategy, inappropriate to assess the sustainable performance of companies, making it necessary to adopt another method that can measure the ecological performance of organizations, such as the fulfillment of certain government objectives (Jackson & Seo, 2010). However, performance assessment measures should vary depending on an organization's state of evolution in terms of environmental management. For example, a company that focuses on complying with the laws in force will tend to adopt evaluation measures in factors related to compliance with these regulations, thus being considered reactive companies, not proactive ones (Hervani et al., 2005).

6 Final Remarks

After this brief analysis, there is no single answer to be taken about how performance assessment systems should be designed and integrated in organizations, when it comes to including parameters for measuring environmental performance. We have seen that the promotion of environmental behaviors can be carried out in several ways, having drawn general lines of what, in principle, can be done in terms of meeting objectives and awarding rewards.

The ISO 14000 standard provides guidance to organizations on how they can proceed, in order to minimize the negative effects caused on the environment, as a

result of their activity, so that better environmental performance can be achieved. However, even with specific criteria, each company is different, and a performance appraisal system must take in account the human factor, not a constant one. For this reason, the ISO 14000 accreditation guidelines have, like ISO 14031, performance indicators described as environmental performance assessment, necessary when evaluating the performance of certain activities, processes, hardware and services (Hervani et al., 2005).

A critical issue to highlight is the role of the manager in this process, and his communication with the employees, because only with a clear understanding of what is intended one can perform any task with that in mind. Thus, performance assessment systems should include an explicit clarification of the environmental objectives to be met, and employees' access to them, as well as feedback to employees for continuous improvement in terms of developing environmental competencies and skills. Clear information on the inclusion of environmental parameters in the organization's practices and the involvement of employees in defining objectives are practical aspects of communication that must be carried out within the organization. Compliance with the objectives may be based on the legislation in force, and may or may not go beyond these parameters, depending on the organization's commitment to being more sustainable and adopting an environmentally friendly posture. Objectives will be more easily achieved with the support of managers.

We also saw that the attribution of rewards allows workers to feel recognition for the effort to practice environmental behaviors, which works as an incentive to adopt them. Thus, the attribution of rewards is a measure to be integrated into the performance appraisal systems which managers see will result in an improvement in the performance of employees. In this way, the fulfillment of objectives, their evaluation, and the result of rewarding workers for the same are integral parts of a performance management system, which is why there must be a conductive line of cause and effect between these parts of that same system.

The structuring of specific performance appraisal parameters, taking in account the case in question, differs from organization to organization, considering its strategy, the profile of its employees, its size, its position in relation to the problem, the practices already adopted, among many other variables, reason why an individualized study of each organization would be the most appropriate.

Finally, although there are already developments in the studies carried out in the area of human resources management in environmental terms, the study of individualized practices of human resources in this scope is still not very advanced, especially in terms of performance appraisal and namely in cases of application practice of existing literature.

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