Doctoral Thesis

Resource Metrics and Consumption Patterns in Hotel Sustainability Benchmarking: Empirical Results from Germany and Austria

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Dissertation

Ressourcenverbrauchsmuster und relevante Indikatoren zur Messung der Nachhaltigkeit von Hotels: empirische Ergebnisse aus Deutschland und Österreich

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Statutory Declaration

I, Alexander Schick, confirm that I have authored the doctoral dissertation titled "*Resource Metrics and Consumption Patterns in Hotel Sustainability Benchmarking: Empirical Results from Germany and Austria,"* consisting of 271 pages. I affirm that I have completed this work independently, without the use of any sources or aids other than those referenced, and that I have not utilized any unauthorized assistance. Furthermore, I declare that this dissertation has not been previously submitted for any formal examination, either domestically or internationally.

Vienna, April 2025 [redacted]

List of Publications

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Abstract

The hotel sector is reportedly one of the most resource-intensive real estate asset classes. This research aims at enhancing the understanding of Energy, Greenhouse Gas (GHG) emissions, Water, and Waste (EGWW) resource management in the hospitality sector by introducing environmental intensity metrics and conducting comprehensive sustainability audits. The thesis is structured into three distinct parts. It commences with a systematic literature review (SLR) by screening 1,596 academic papers and identifying 117 to analyze in the context of environmental intensity metrics assessment, benchmarking audit results as well as influencing variables on hotel real estate operations. Following the initial literature review, a mixed research approach using a sequential design is defined for the empirical work in this dissertation. In the second part, a qualitative study that included 16 semi-structured expert interviews clustered into four stakeholder groups is conducted. Insights from the interviews are used to narrow down the metrics further and align them with the latest legislative regulations and the chosen geographical setting. As a result, a set of intensity metrics referring to energy and environmental performances is designed and grouped based on the operational and physical attributes of hotel properties. The third part of this work is a quantitative phase, where a data set consisting of 301 hotels is analyzed and further enriched with the findings of previous research phases. Providing descriptive analyses, correlation, and regression models, deeper insights into the environmental performance of the German-Austrian hotel industry are gained. There, empirical evidence is found that resource consumption is strongly affected by quality level, scope of services, location, and existence of resource-intensive outlets such as wellness areas. Significant results of multiple linear regression models with R^2 above 0.6 point out the interdependence of normalized energy and water consumption. Decision makers, academics, and hoteliers benefit from the defined intensity metrics and environmental auditing results, which provide an outline to monitor and benchmark resource efficiency in hotel real estate.

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1. Introduction

1.1. Background and Rationale

According to the UN Enironment Programme (2020) approximately 38% of global Carbon Dioxide (CO_2) emissions are attributable to the real estate industry. What is more, tourism significantly contributes to GHG emissions, being responsible for 5% of global CO_2 emissions (UNWTO, 2023), with 21% of those emissions due to the hotel sector (hotels and other lodging units) (UNWTO, 2019). Lenzen et al. (2018) estimate that 8% of worldwide GHG emissions are produced by the tourism industry. Gössling et al. (2023) concluded that without worldwide policy efforts to manage the sector's emissions, tourism will deplete 40% of the world's remaining carbon budget and become one of the significant drivers of climate change. To counteract this process, the UN World Tourism Organisation (2021) announced the plan according to which CO_2 emissions of the whole industry are to be reduced by 50% by 2030. In addition, the Sustainable Hospitality Alliance reports that, based on 2010 levels, to reach the Paris Agreement targets, hotels need to lower the carbon emissions per room by 66% by 2030 and 90% by 2050 (Sustainable Hospitality Alliance, 2017). The increasing awareness of the global ecological situation is partly responsible for environmental protection-related legislative measures. In this context, commercial and special-purpose properties, such as hotels, are particularly negative examples (Dibene-Arriola et al., 2021; MacAskill et al., 2023). Furthermore, the active management and conservation measures of "resource real estate" are coming to the fore due to declining profits, an intensified competitive situation, and rising resource costs. This is further exacerbated by the fact that the priority of most hotel businesses is to recover from the drawbacks of Coronavirus pandemic rather than reduce emissions (UNWTO, 2023). Furthermore, worldwide environmental, social, and economic problems such as climate change, water crises, gender equality, poverty, as well as legislative policies such as the EU Green Deal, have led to more significant concern about sustainability (Eckert and Kovalevska, 2021; Madanaguli et al., 2023).

Being an ever-evolving concept, sustainability reporting is known under various synonyms – non-financial reporting, corporate social responsibility (CSR) reporting or sustainable development (SD) reporting (Zrnić et al., 2020). Calabrese et al. (2017) define sustainability reporting as *"the practice of measuring, disclosing, and being accountable to internal and external stakeholders for the company's ability to achieve sustainable development goals and manage impacts on society*". A discussion of the development of the term is presented in the study of Bebbington and Larrinaga (2014). In recent years, the term has evolved to encompass Environmental, Social, and Governance (ESG) matters, with a stronger emphasis on measurable outcomes and accountability

(Passas, 2024). The Corporate Sustainability Reporting Directive (CSRD), European Sustainability Reporting Standards (ESRS) and various other legal acts[1] of the European Union form the ESG legal framework, which is intended to create a coherent flow of sustainability information along the financial value chain and thus prevent greenwashing. What is more, the European Union Action Plan includes the "*development of sustainability benchmarks*" as part of its specified set of measures (European Commission, 2018, p. 8 f).

The operational implementation of the ESG requirements is primarily the responsibility of the Facility Management (FM) department of a company (Graichen, 2021; Jensen et al., 2024). In the early studies on FM in the real estate sector, De Groote (1995), Douglas (1996) as well as Cable and Davis (2004), highlighted inefficiencies and emphasized the need for key performance indicators. Amaratunga et al. (2000) argued that measurability is essential for management and control tasks within companies. In the study of Jensen et al. (2024, p. 29) it was concluded that "*FM is an important input provider, as well as strategic partner to companies working with the sustainability agenda.*" Practice-oriented initiatives for real estate benchmarking are available in the publications of the German Facility Management Association (GEFMA), including *GEFMA 160 SustainFM*, which serves as the foundation for the development of a specific sustainability concept (Grim-Schlink and Kuchar, 2022). Nevertheless, given that FM is a broad research field, and hotel operations represent a specific subset of FM, the focus is subsequently narrowed to literature pertinent to the hospitality sector.

As described by Kirk (1996), the hotel operation comprises a large number of small operations, each of which consumes relatively small amounts of resources. Collectively, resource consumption and environmental impact are large (Xuchao et al., 2010). In addition, the operations phase, with its operational energy and consequent GHG emissions, is the most critical phase of the property life cycle, both in terms of duration and cumulative expenditure (around 90% of total life cycle cost), and is therefore decisive for the ecological footprint of companies (Blengini, 2009; Filimonau et al., 2011; Rønning and Brekke, 2014). Other authors such as Rosselló-Batle et al. (2010) concluded

[1] Legal acts on ESG issues include: Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large companies and groups; NaDiVeG; Regulation 2019/2088/EU of the European Parliament and of the Council of 27 November 2019; Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 establishing a framework to facilitate sustainable investment; Directive 2004/109/EC, Directive 2006/43/EC and Commission Delegated Regulation (EU) 2023/2772 of 31 July 2023.

that energy use in the operation phase is 4 to 6 times greater than in the planning and construction phases. Accordingly, this phase offers the highest potential for achieving significant reductions in resource consumption (Cunha and Oliveira, 2020; Rosselló-Batle et al., 2010; Tao and Huang, 2014; Jones et al., 2014). This results in different resource consumption profiles, and numerous studies indicate that resource usage of hotels is among the highest of all building types (Deng and Burnett, 2000; Filimonau et al., 2011; Rottke, 2017). A recently published industry report reveals that with 96 $kgCO_2e/m^2$, hotels are among the most resourcing-consuming industries together with healthcare (around 100 $kgCO_2e/m^2$) and considerably higher than office (around 85 $kgCO_2e/m^2$) and retail (around 60 $kgCO_2e/m^2$) (CBRE, 2023). This is mainly due to the high service intensity and a multitude of functional facilities depending on the concept (e.g., restaurants, swimming pool, gym), variability of occupancy levels and seasonality as well as 24 hours of operation (Guzzo et al., 2020). Authors increasingly stress that defining metrics and developing mechanisms for sustainability issues is essential (Jones and Comfort, 2019). The need to measure and monitor resource use is tremendously important for a multitude of activities, for example, as part of an annual benchmarking process, (Bohdanowicz and Martinac, 2007; Deyà Tortella and Tirado, 2011), through audits (Becken, 2013), in relation to refurbishment (Barberán et al., 2013), and to understand opportunities for new technology (Coles et al., 2016). All this requires a fundamental change in entrepreneurial thinking towards ecological and sustainable concepts along the life cycle of a hotel property and its operation.

For decades, the hospitality sector has developed and applied green practices to mitigate its environmental footpath in its facility operations (Han et al., 2018; Jones et al., 2016; Kim et al., 2016; Madanaguli et al., 2023) and to reduce the global carbon footprint subsequently (Teng et al., 2012). According to key findings of a study done by Accenture in 2022 more than 90% of hotel owners responded that environmental pressure is constantly increasing from customers, investors, employees, and property's brand organization (de Maar et al., 2023). Green practices in the context of hospitality can thereby be defined as "*a value-added business strategy that benefits a hospitality operation that engages in environmental protection initiatives*" (Kim et al., 2017, p. 236). Caused by the increasing interest in sustainability reporting, a plethora of schemes including methods, calculators and measuring tools (e.g., HCMI, Net Zero Methodology for Hotels), reporting standards (e.g., GRI; SASB), certification programs (e.g., EMAS, ECO-Label), and energy management frameworks (e.g., ISO 14001, ISO 50001, ISO 50004) developed for companies of all sizes. As shown in existing sustainability reports of the largest hotel companies in the world, hotels merely share their environmental practices and some achievements on the web, providing insufficient quantified figures for GHG reduction (Chan, 2012; Lau et al., 2021) as well as the need to improve environmental accounting and reporting practices (Janković and Krivačić, 2014). Research found that reuse programs in linen, energy-efficient light bulbs, green purchasing, water conservations as well as waste water treatments are among the most popular green practices in the hospitality industry (Acampora et al., 2022; Manganari et al., 2016). Nevertheless, as postulated in recent publications, initiatives in scientific and existing standards and certifications seems still ineffective (Agyeiwaah et al., 2017; Legendre et al., 2024). Furthermore, as highlighted by Antonova et al. (2022), existing literature shows only limited progress in the development of indicator-driven management systems.

While sustainability practices and standards have seen global development, their real-world application and effectiveness can vary significantly across regions. To explore this dynamic within a Central European context, this work focuses on Germany and Austria as representative examples. The two countries, along with their respective hotel markets, share many similarities, driven by their geographic proximity, well-developed tourism offer, and high standards for sustainability and quality. Both countries have robust hospitality sectors that cater to a mix of business and leisure travelers, with a strong emphasis on cultural tourism, wellness retreats, and urban accommodations (HVS, 2024). Major cities such as Vienna, Salzburg, Berlin, and Munich attract international visitors, while alpine and rural areas benefit from seasonal tourism, particularly for skiing and outdoor activities. Additionally, the hotel industries in both countries are increasingly focused on sustainability, digitalization, and energy efficiency, aligning with stringent environmental regulations and consumer expectations. Importantly, as member states of the European Union, Germany and Austria operate within the same legislative framework, including compliance with evolving sustainability reporting requirements such as the EU Taxonomy. Given these commonalities, market trends, benchmarking practices, and operational challenges in Germany and Austria often follow parallel trajectories (HVS, 2024). Therefore, in this research, Germany and Austria are regarded as a unified market, collectively referred to as the German and Austrian hotel industry.

Despite the inherent necessity to build a sustainable image and enhance brand value, reputation, and legitimacy to a diverse set of internal and external stakeholders (Agudo-Valiente et al., 2015), a still challenging approach is to follow the holistic integration of sustainability in business strategy through operational practices (Gond et al., 2012) and enhance life cycle thinking (Kaenzig et al., 2011). Therefore, this research generally follows the inherent call of several authors such as Manning (1999), Cheong and Lee (2021) and Back (2024) formulating sustainability indicators for the operating system of a hotel and promoting measurement of emissions. This requires the development of a more comprehensive, integrated approach to incorporate sustainability management into accounting and reporting practices (Jones et al., 2016; Linnenluecke et al., 2015; Schaltegger et al., 2022). Furthermore, corporations and their stakeholders are vital actors when it comes to mitigating the impacts (Schaltegger et al., 2017). Therefore, increasing pressure is inherited to measure, manage, and report performance matters in sustainability (Kotsantonis and Serafeim, 2019; Schaltegger and Burritt, 2010) buzzing around strategy, operations, and financial objectives (Calabrese et al., 2019). Lee et al. (2021) investigated a multitude of sustainability indicators and concluded that the environmental aspects have the highest relevance for tourism experts. In this light, energy, water, and waste audits represent key approaches to measuring and monitoring environmental performance (Diamantis and Westlake, 1997; Warnken et al., 2004). Therefore, this study is primarily focusing on the development and analysis of intensity metrics and benchmarks for Energy, GHG emissions, Water, and Waste (hereafter referred to as EGWW) in the German and Austrian hotel industry.

1.2. Aim and Objectives

As introduced in the previous chapter, the topic of environmental intensity metrics in the hotel industry remains underdeveloped, with no standardized set currently in place. Therefore, the aim of this research project is to identify, collect, and categorize indicators in the field of EGWW to measure and benchmark hotel real estate operations. A further focus is placed on the validity and reliability of the encountered benchmarks by analyzing legislative fundamentals, resource audit results as well as the factors affecting resource consumption in hotel real estate operations. The findings encountered via a scientific literature review and a qualitative phase are subsequently applied to a quantitative dataset, enabling the derivation of conclusions regarding their applicability and validation. As a result, measurable metrics as well as valid benchmarking values, are generated for academics and practitioners alike. To reach the core aim of this study, four sub-questions were formulated to break down the work and ensure a more strategic approach to the research:

- What are the main EGWW intensity metrics for the hotel industry? Which environmental field is most researched? What are the audit results of EGWW metrics in the hotel industry?

- What legislative considerations should be taken into account when developing environmental indicators?
- How should hotels be clustered to generate valid benchmarking? What are the significant dependent characteristics that influence the identified intensity metrics?
- How can resource consumption in the German and Austrian hotel industry be accurately forecasted?

Further hypotheses are elaborated in Chapter 4 to consequently answer the above set of research questions. To be able to answer the four sub-questions, the following research steps are set:

- To conduct a systematic literature review to identify existing intensity metrics for benchmarking resource consumption in the hotel industry, examine dependent characteristics influencing resource use, and analyze corresponding audit results and research frequency.
- To assess the legislative foundations of resource consumption reporting, including the CSRD and ESRS frameworks, and evaluate current benchmarking techniques, environmental initiatives, and audit data from leading international hotel companies.
- To perform expert interviews in order to evaluate the current state of environmental benchmarking and reporting practices—specifically for energy, water, waste, and GHG emissions—in the hotel industry, and to align insights with the needs of German and Austrian hotel companies.
- To collect empirical data on resource consumption and dependent characteristics from hotels in Germany and Austria, apply the identified intensity metrics, and evaluate the effectiveness of clustering techniques.
- To develop a resource consumption model using regression analysis based on significant dependent variables and identified consumption patterns.
- To synthesize findings and assess the practical applicability of the results in light of the literature review and expert insights.
- To identify theoretical and practical implications of the findings for industry stakeholders, policymakers, and the scientific community.

A detailed overview of the research design, including the methodological approach and data collection process, is provided in Chapter 4.4.

1.3. Thesis Structure

This doctoral thesis is structured into seven chapters, each of which serves a distinct purpose in advancing the research objectives and contributing to the overall understanding of the research problem. Figure 1 provides a schematic overview of the chapters and their contents.

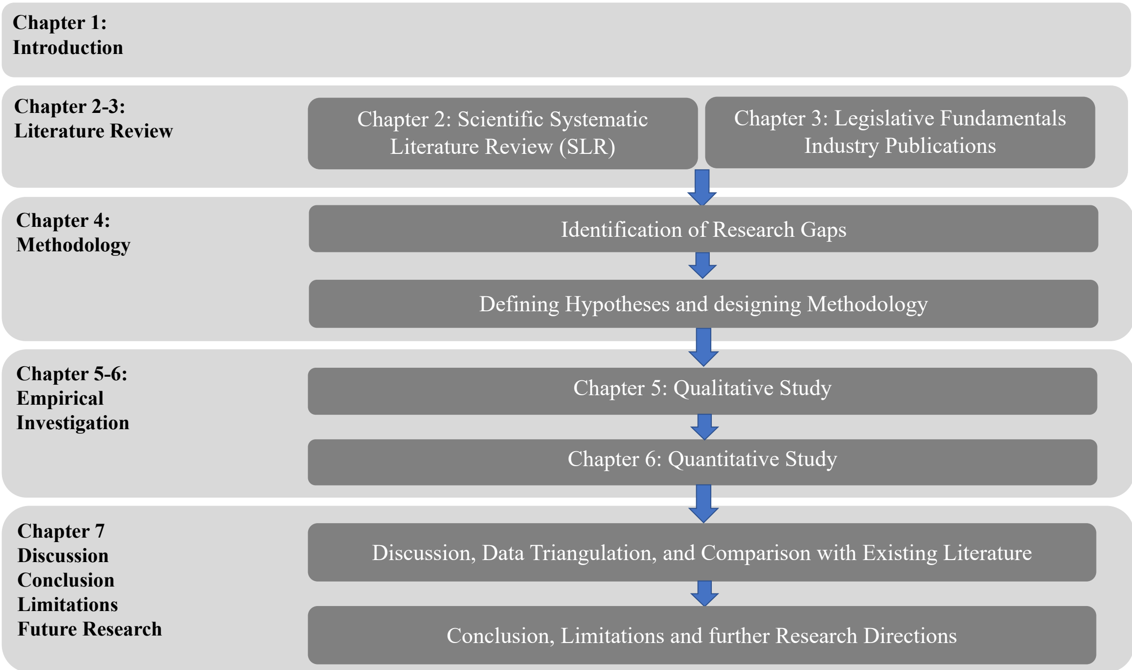


Figure 1: Thesis Structure
Source: Author's own data

Following the introduction chapter, *Chapter 2* commences with a systematic literature review. The methodology is detailed, including the search strategy, selection criteria, and synthesis methods. Then, the chapter presents the findings, highlighting key themes and trends, identifying relevant intensity metrics for resource consumption in the hotel industry, and discussing the main determinants influencing consumption patterns. Furthermore, a compact analysis of legislative fundamentals as well as existing initiatives is conducted in *Chapter 3*. *Chapter 4*, the methodology section, identifies research gaps and highlights the study's novelty before presenting the research design, sampling strategy, data collection methods, and data analysis procedures used in the empirical part of this thesis. In addition, the sequence explains the rationale behind the chosen methodology, ensuring transparency and rigor in the conducted empirical research procedures. Subsequently, 26 hypotheses are developed and detailed for testing in the empirical analysis. The following two chapters present the empirical findings of the study, divided into a qualitative phase (*Chapter 5*) with 16 semi-structured expert interviews and a quantitative phase (*Chapter 6*) analyzing and applying findings on a data set of around 300 hotels located in Germany and Austria. Further details of the empirical investigations are elaborated on and explained in the aforementioned methodology chapter. The discussion and conclusion chapter (*Chapter 7*) critically examines the research findings, interpreting their implications and discussing their significance in relation to existing literature. Furthermore, the study concludes with an analysis of its overall significance, emphasizing key implications for theoretical advancement, practical application, and future research. It also includes a critical reflection on the research process, acknowledges its limitations, and outlines avenues for further investigation to deepen understanding within the field.

2. Systematic Literature Review (SLR)

In the first step, a literature review is executed to assess the current state of research and to provide an overview of previous scientific research. Saunders et al. (2012) highlight that a literature review enables the researcher to develop theories from past knowledge as well as build the conceptual framework necessary for the research process. The overall purpose is not to provide a summary of everything that has been written but to review the most relevant and significant research on the chosen topic (Breslin et al., 2020; Saunders et al., 2012). Authors such as Tranfield et al. (2003) and Saunders et al. (2012) underline the importance of reporting the literature search strategy to ensure that the research is replicable and transparent. Therefore, in the following methodology section a short outline of the conducted research process for the literature review will be provided.

2.1. Literature Review Methodology

When writing a literature review the basics of teleology process theory have to be internalized. Therefore, a generic story which describes a sequence of events is obligatory (van de Ven, 1992). The process is strongly depending on the chosen research approach and should be constructed adaptable, with a possible movement back and forth between the stages (Juntunen and Lehenkari, 2021). In the study of Snyder (2019) a process model was developed out of well-known literature review standards (e.g., Okoli, 2015; Saunders et al., 2012; Tranfield et al., 2003; Wong et al., 2013; Templier and Paré, 2015), consisting of four main steps – designing the review (1), identification of articles / conducting the review (2), critical review (3), and dissemination (4). This model was also used by most recent literature review articles with a focus on environmental accounting for business studies (e.g., Schaltegger et al., 2022) as well as specifically in the given research field tailored to the tourism industry (Acampora et al., 2022; Antonova et al., 2021; Warren and Becken, 2017). Furthermore, the stages are in line with the proposed data analysis technique of Grounded Theory, highlighting that the stages are intended to be a guide to help systematize the existing literature (Wolfswinkel et al., 2013).

2.1.1. Phase 1: Designing the Review

When it comes to designing the review, the most common research approach in business-related topics is a systematic or semi-systematic literature review (Davis et al., 2014; Ferrari, 2015; Snyder, 2019). Systematic Review is defined as a process for reviewing the existing literature using a comprehensive preplanned strategy, assessing the contribution, analyzing and synthesizing the findings, and reporting the evidence to allow conclusions to be reached about what is known and, also, what is not known and therefore specifically useful where topics are still fragmented and interdisciplinary (Denyer and Tranfield 2009). Often, the findings are analyzed using the meta-analysis approach, which generally is in need of randomized controlled trials. Although fragmented guidelines for social sciences exist (Davis et al., 2014; Palmatier et al., 2018), meta-analysis is less common as statistical data and measures are necessary to compare results and are therefore challenging to perform with existing studies using different methodological approaches (Tranfield et al., 2003). Thematic or content analysis is a common technique to synthesize findings within a SLR. As a result, a map of research, synthesizing the state of knowledge or creating an agenda for further research, is commonly created (Snyder, 2019).

As highlighted by Hansen and Schaltegger (2016) the chosen research field is highly interdisciplinary, requiring the search for publications across different disciplines such as finance, management, accounting, and sustainability. Therefore, besides the predominantly focused publications on peer-reviewed journals, contributions published in conference proceedings, professional body journals, books, PhD-dissertations, or reports by professional bodies are included for completion. The authors of the latter publications are commonly associated with the academic community in hospitality/real estate management and/or accounting studies and/or environment sciences. Furthermore, articles addressed to the business community (such as the "Big Four"[2] accounting firms), existing international environmental frameworks (e.g., GRI, MSCI, SASB) or international organizations (e.g., European Union), and NGOs (such as the UN or UNWTO) are recognized within this literature review. To avoid repetition, when being developed into a publication, working papers are not considered, and the final publication is counted. The decision to take such a broad range of authorships and publications is based on the novelty of the research topic and the associated inherent influence of international, political, and professional organizations (Schaltegger et al., 2013).

[2] The "Big Four" is the sobriquet used to refer to the four largest accounting firms in Europe, as measured by revenue - Deloitte, Ernst & Young (EY), PricewaterhouseCoopers (PwC), and Klynveld Peat Marwick Goerdeler (KPMG).

Pre-specified exclusion and inclusion criteria are set to narrow down the list of articles and to answer research questions (Snyder, 2019; Wolfswinkel et al., 2013). Thus, possible bias can be reduced, and conclusions can be drawn from existing knowledge (Davis et al., 2014). Since over 90% of scholarly publications are in English (Montgomery and Crystal, 2013), and given the researcher's geographical location, this SLR includes publications in both English and German. Therefore, it is unlikely that a major finding is missed due to the language issue. In terms of geographical location, no exclusion is taken, thus covering relevant publications all around the world within the set boundaries of research. Furthermore and contrary to previous literature reviews in this field, the journal selection is not restricted to only tourism-related literature (e.g., in the SLR of Acampora et al., 2022 or Kim et al., 2017) or limited database use (e.g., solely use of Scopus database in the SLR of Reem et al., 2022) or any restrictions of the article's publication date (only collecting research from specific publication years in the SLR of Antonova et al., 2021 or Campos et al., 2024). Nonetheless, a rigor exclusion process is conducted with articles not fulfilling the following aspects:

Exclusion of articles

- not related to EGWW measurement
- related to the broad term of tourism, not directly related to the hotel industry;
- similar to the study of Cheng et al. (2020), other accommodation forms such as hostels, serviced apartments, or villas are excluded from analysis[3];
- predominantly analyzing partial areas of a hotel (e.g., only restaurant, only laundry);
- analyzing guests or hotel employees perspectives on sustainability in the tourism industry or sustainable hotel operations (such as Carvalho and Oliveira, 2022);
- studies based on simulation and mathematical modeling, without the use of real-world hotel data (González and Yousif, 2015; Nguyen and Rockwood, 2019);
- listing non-measurable, non-countable indicators;
- listing indicators related to monetary calculations and benchmarking (e.g., energy bills) as comparability is limited across different regions;
- not related to the operational phase of the hotel real estate life cycle (e.g., construction or planning phase).

[3] Although some keywords encompass service-intensive accommodation types, and the perspective of real estate operations, only articles pertaining to the hotel industry are deemed as relevant.

2.1.2. Phase 2: Identification of Relevant Articles

The review is conducted within the next phase of the process, and the actual selection of articles takes place. Several authors state that the literate review will always be a limited set of all papers on the topic, i.e., to impose a stratified selection to answer the selected research question(s) (Snyder, 2019; Wee and Banister, 2016). The research process was performed as follows: After an initial brainstorming, a non-structured literature search of the main related terms as suggested by Tranfield et al. (2003) to gain a broad overview was executed. Furthermore, the concept of relevance trees or mind mapping was used to identify research topics and structure them accordingly (Jankowicz, 2006; Sharp and Peters, 2017). Then, from the mind map, a pre-specified list of keywords and search terms was defined for each research sub-topic. Abbreviations, synonyms, alternative spellings, and related terms were searched accordingly (Xiao and Watson, 2019). The review started by conducting the central online databases for academic literature collection Web of Science and Scopus (Chadegani et al., 2013). Google Scholar was screened as a final step to find any additional information on the bespoke topic. These databases were chosen due to their comprehensiveness of databases like ProQuest and Science Direct as well as publications issued by Emerald, Springer, Wiley/SAGE, Taylor & Francis. Second, scholarly publications such as books, conference proceedings as well as high-quality industry publications were reviewed (Juntunen and Lehenkari, 2021; Tranfield et al., 2003; Xiao and Watson, 2019). When searching in the literature, a combination of search terms was formed to search strings, and the so-called Boolean logic was used. This concept links the defined keywords together with AND, OR, and NOT combinations (Jalali and Wohlin, 2012; Ridley, 2012; Wee and Banister, 2016).

Table 1 illustrates the keyword groups divided into three sectors. The first group covers the broad term of “sustainability” in all possible meanings. The second group aims at addressing the “framework” to actually compare and contrast the topic. The third group refers to the entity under investigation, i.e., the hotel industry. The groups derived from well-known industry publications and their clustering techniques (Freyer, 2015; Rutherford and O’Fallon, 2007). The use of asterisks in all keyword groups ensured that different suffixes were included. As a result, comprehensive data triangulation was achieved by snowball and trial-and-error sampling using peer-reviewed journal search, database query, and internet-based search.

Group 1: in the title or keyword or abstract (linked intra-group with OR connector)
environment* OR ecologic* OR sustainab* OR climate* OR corporate responsib* OR carbon* OR green* OR greenhouse gas* OR waste OR water OR energy OR esg OR social responsib* OR sdg* OR governance OR triple bottom line* OR emission* OR health & safety* OR csr
Linked with AND connectors to
Group 2: in the title or keyword or abstract (linked intra-group with OR connector)
account* OR management approach OR materiality process* OR benchmark* OR management system* OR management* OR intensity indicator* OR model* OR balanced scorecard OR management tool* OR framework* OR performance* OR measure* OR development* OR system* OR index OR kpi* OR indicator* OR report* OR life-cycle* OR assessment* OR audit* OR index* OR consumption*
Linked with AND connectors to
Group 3: in the title or keyword or abstract (linked intra-group with OR connector)
facilit* management OR facilit* service* OR hotel* OR motel* OR lodging OR accommodat* OR hospitality OR tourism OR real estate operation* OR service industr* OR food & beverage OR restaurant* OR resort*
Please note: The symbol * is used to include all possible variations of a word (e.g., benchmark instead of benchmarking).

Table 1: Keyword Groups
Source: Author's own data

As suggested by Denyer and Tranfield (2009), and Xiao and Watson (2019) selection and evaluation of the studies were taken by skimming the title and abstract. Whenever the relevance was perceived as high, the full text was read. Despite the rigorous review, the full-text analysis revealed that a multitude of articles did not have the desired main focus and were subsequently excluded. As the research developed, the key authors in the field were identified. Using the citation index, additional articles were located. To further enrich the research database, an iterative backward and forward snowballing technique was employed, which involved identifying additional relevant articles through the reference lists of the initial articles (Jalali and Wohlin, 2012; Wee and Banister, 2016; Xiao and Watson, 2019). Likewise to similar literature reviews (e.g., Morioka and de Carvalho, 2016), trial-and-error (testing combinations with filters) was carried out while researching. Authors such as Denyer and Tranfield (2009) and Saunders et al. (2012) suggest undertaking an exploratory scoping study to assess whether a systematic review of the research topic have already been published. It has been revealed that the term "hotel" is too narrow. Therefore, the focus has expanded to include service-intensive accommodation types and the perspective of real estate operations. Nevertheless, only articles related to the hotel industry were included according to the defined exclusion criterias. To assess the sufficiency of the literature coverage, key authors in the field were identified, and subsequent searches were cross-checked to determine whether newly found sources primarily reference works already reviewed (Saunders et al., 2012).

2.1.3. Phase 3: Critical Review of Articles

The analysis section of the conducted research deals with abstracting and making sense of relevant information (Bearman et al., 2012; Snyder, 2019). Furthermore, similar data was conceptually categorized and grouped together. Alongside the chosen research approach, the corresponding synthesis emerged around the researcher's expertise and from the literature (Rowley and Slack, 2004). When reviewing literature, as indicated by Sharp and Peters (2017), the relevance to the own research was assessed as well as bibliographic details and a summary of content were given. Nevertheless, it must be noted that subjective criteria (e.g., personal knowledge, brainstorming with experts and supervisor) were considered when identifying relevant articles and implementing a final research matrix (Wee and Banister, 2016). Wherever possible articles were downloaded in PDF format and stored in a software for managing references. The collected data was subsequently analyzed in an Excel formatted codebook using a concept matrix, which changed over time as research evolved (Webster and Watson, 2002; Wolfswinkel et al., 2013). The assessment of study quality (e.g., methodological rigor) was not further investigated due to the quality level of the underlying research databases identified. Validity is considered the extent to which the chosen research method accurately measures what it intends to measure (Saunders et al., 2012). This was secured by following the guidelines building on the concept of Tranfield et al. (2003) that has already been used by various other literature reviews within this research field (Hahn and Kühnen, 2013; Hansen and Schaltegger, 2016; Pranugrahaning, 2021; Schaltegger et al., 2022; Stechemesser and Guenther, 2012).

2.1.4. Phase 4: Analysis and Dissemination

Several quantitative (e.g., meta-analysis, frequency analysis) and qualitative (e.g., thematic analysis, narrative analysis, grounded theory) methods and techniques exist for synthesizing the collected data (Dixon-Woods et al., 2005; Paré et al., 2015). For the SLR, the Grounded Theory approach created by Glaser and Strauss (2010) was used. This analysis involves specific stages, precisely the open coding stage (data is chunked into high-abstraction level type categories, which are then assigned a code), the axial coding stage (the collected codes are grouped into categories and sub-categories), and the selective coding stage (categories are integrated, contrasted and refined) (Onwuegbuzie et al., 2015; Wolfswinkel et al., 2013). When sub-categories emerge, comparative analysis continuously relates, compares, and links the identified categories to refine the concept (Wolfswinkel et al., 2013). As a result of *Phase 3*, researchers are often confronted with unstructured single empirical notes from the academic publications under investigation (Wolfswinkel et al., 2013). As a result of the coding steps, this method enables the researcher to identify significant patterns within the collected data and build a robust theoretical framework. Furthermore, the connection between the identified patterns and categories is revealed. A framework was abductively developed by iteration of the data using the underlying codebook. The last part of the process is associated with the writing process or dissemination and the respective reporting scheme of the analysis to express essential aspects of the review. The overall task is to write the review academically and assess the overall approach and whether the findings are synthesized in a clear and valuable way (Jesson et al., 2011). Regarding the visualization of results, tables and figures are used (Juntunen and Lehenkari, 2021). Table 2 provides a summary of the main activities conducted in this SLR:

Phase 1 – Formulation of Search Terms	**Phase 2 – Identification of relevant Articles**	**Phase 3 – Critical Review**	**Phase 4 – Analysis and Dissemination**
- Development of ideas about the focus of the literature review and discussion with other researchers - Elaboration on literature review process techniques - Exploratory search on databases such as Google Scholar - Definition of a set of inclusion and exclusion criteria - pre-set of data storage and analysis medium	-Definition of keywords for sample selection as well as categorization in groups - Search mediums definition (Primary, secondary, tertiary literature) - Application of keywords in the chosen databases - Back and forth snowballing, taking into account expert recommendation - Selection of studies: Initial paper sample based on criteria defined in previous stage	1st Pre-read of Title and abstract: Elimination of papers according to exclusion criteria non-related to the research focus 2nd Full paper review, with focus on introduction, research method and conclusions as well as environmental KPIs 3rd Focused readings: deep content analysis, categorization - Scientific processing and categorization in electronic spreadsheet	- Data synthesis: Elaboration of tables and figures to illustrate the main findings of analysis. - Grounded Theory and constant comparative analysis by Glaser and Strauss (1967) - Writing process of final document - Proposal of a conceptual framework

Table 2: Stages of Research
Source: Author's own illustration, adapted from Tranfield et al. (2003) and Morioka and de Carvalho (2016)

Applying the above-described procedure, the initial search resulted in 1,596 articles. The application of the defined exclusion criteria to abstracts and full texts, as well as the removal of duplicates, narrowed down the publication set. The literature references of articles in this preliminary set were screened for further publications meeting the above criteria as well as the expert opinion was consulted, resulting in 53 additional publications. Following the application of the exclusion strategy illustrated in Table 3, a final set of 117 papers from 1979 to 2024 were eligible for data extraction. The final set included 100 articles from peer-reviewed academic journals, as well as 17 articles sourced from dissertations, books, and book chapters.

Database from origin to February 2024	Scopus	Web of Science	Total
First scan - citations	702	894	1,596
Data cleaning, removal of duplicates and incorrect entries	-34	-66	-100
Data cleaning, adjustment to exclude non-english, non-german articles	-5		-5
Articles after data cleaning	663	828	1,491
Reading of title and abstract according to defined exclusion criteria	-510	-765	-1,275
Articles subjected to full text review	153	63	216
Exclusion based on full text review	-101	-51	-152
Articles included after full text review	52	12	64
Snowballing, expert opinion			53
Total			**117**

Table 3: Exclusion Strategy Process
Source: Author's own data

2.2. Previous SLR on the Topic

While the research field is still evolving, several authors have contributed to the topic by performing SLR. Some of these give a broad overview of research related to sustainability in tourism (Acampora et al., 2022; Arici et al., 2024; Balas and Abson, 2022; Kim et al., 2017) or hotels specifically (dos Santos et al., 2017; Kim et al., 2019). Acampora et al. (2022) observed in their study that green practices in the hotel industry are missing a framework or theory behind the analysis and categorization of findings. Regarding hotels and sustainability indicators several authors discussed the topic from different perspectives. Reem et al. (2022) performed a SLR with a focus on sustainability indicators for the hotel industry. In the study, 29 articles and 356 indicators were extracted from the SCOPUS database. Categorization was done by creating four groups of indicators, revealing 149 environmental indicators, 96 economic indicators, 53 sociocultural indicators, and 64 sustainability management indicators. Nevertheless, it has to be acknowledged that most of the found indicators are descriptive and not continuously measurable over a certain time horizon. Especially the paper of Campos et al. (2024) established a framework consisting of 24 environmental indicators, revealing that energy consumption per floor area, water consumption per room night and guest night are most relevant in the hospitality industry. Furthermore, disparities between scientific literature, consultancy firm publications as well as technical books were highlighted. Antonova et al. (2021) discussed water resources issues in the hotel industry and revealed 58 articles of relevance. Classification of the results was done into four groups – water consumption, water management, impact of water use and good practices. Especially within the group of water consumption the necessity of audits and measurement of water resources within hotels was highlighted. A research study predominantly dealing with energy and water benchmarking was published by Warren and Becken (2017). The identified 110 papers were clustered into management and practices, engineering, technology and design, guest behavior, and auditing/measurement. The latter is especially important for the use of this study and highlights the importance of external factors such as the origin of guests, hotel characteristics, or climate when comparing the environmental consumption of hotels. The paper of Dibene-Arriola et al. (2021) solely focused on energy efficiency indicators for hotel buildings. Out of the 26 articles of interest, a list of 21 indicators highlighting that the most used indicator was the total average annual energy use intensity index per gross floor area (kWh/m²) ranging from 60 to 700 kWh per floor area. The study also revealed that hotels in tropical climates use more energy than hotels in continental zones. Furthermore, numerous non-systematic literature reviews were published on the topics of the transition of tourism research from CSR to ESG (Legendre et al., 2024), environmental accounting practices (Janković and Krivačić, 2014), energy research in hospitality (Xu and Dan, 2023), or of water issues in hotels (Gössling et al., 2012).

2.3. Analysis of Publication Trends, Research Focus, and Methodologies

This section presents a structured overview of the reviewed literature, focusing on publication trends, key research areas, and methodological approaches. It highlights how the field has developed over time by analyzing publication frequency, major journals, geographic focus, sample characteristics, and commonly applied research methods.

2.3.1. Distribution over Time

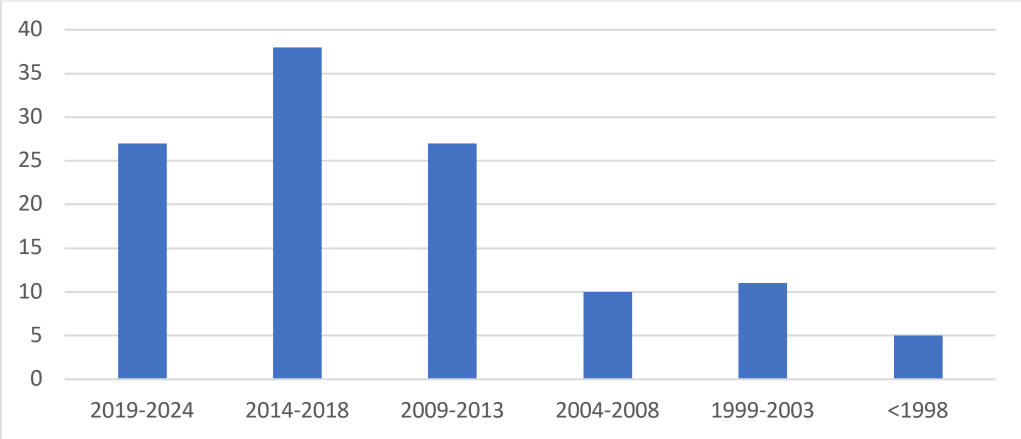


Figure 2: Year of Publication Analysis
Source: Author's own data

Figure 2 shows the yearly evolution of publication numbers and reveals a growing pattern; the majority of articles (56%) were published within the last 10 years. Before 2000, the interest in the topic is revealed as limited. This development is in line with the adoption of the initiation of Sustainable Development Goals (SDGs) as well as the *2030 Agenda for Sustainable Development* (United Nations, 2015a) and indicates that the interest in the field under investigation is of increasing importance.

2.3.2. Key Journals Contributing to the Research Topic

Journal Title	Publisher	Topic	Publication Count	Country
Energy and Buildings	Elsevier	Building Science	**19**	United Kingdom
International Journal of Hospitality Management	Elsevier	Hospitality	**10**	United Kingdom
Journal of Cleaner Production	Elsevier	Environmental Management	**7**	United Kingdom
Sustainability	MDPI	Environmental Management	**6**	Switzerland
Tourism Management	Elsevier	Hospitality	**4**	United Kingdom
Renewable Energy	Elsevier	Environmental Management	**3**	United Kingdom
Ecological Economics	Elsevier	Environmental Management	**2**	United Kingdom
Energy Policy	Elsevier	Environmental Management	**2**	United Kingdom
International Journal of Contemporary Hospitality Management	Emerald Publishing	Hospitality	**2**	United Kingdom

Table 4: Contributing Journals
Source: Author's own data

The identified 117 articles are published in a total of 50 different journals. The most significant journal as shown in Table 4 is *Energy and Buildings* with a total of 19 articles followed by the *International Journal of Hospitality Management* with 10 papers. It is worth noting that the identified journals have a business and management, sustainability, building science as well as hospitality background, indicating the multitude of areas involved in research on corporate sustainability issues in the hotel industry.

2.3.3. Geography of First Author and Sample Location

Figure 3 illustrates the geographical origin of the first author of each paper and the location of the data set under investigation. With regards to the authorship, it is revealed that Asia (43 articles) and Europe (43 articles) were the most prominent. More precisely, most of the studies were done in Southern Europe (28 articles) and Eastern Asia (29 articles).

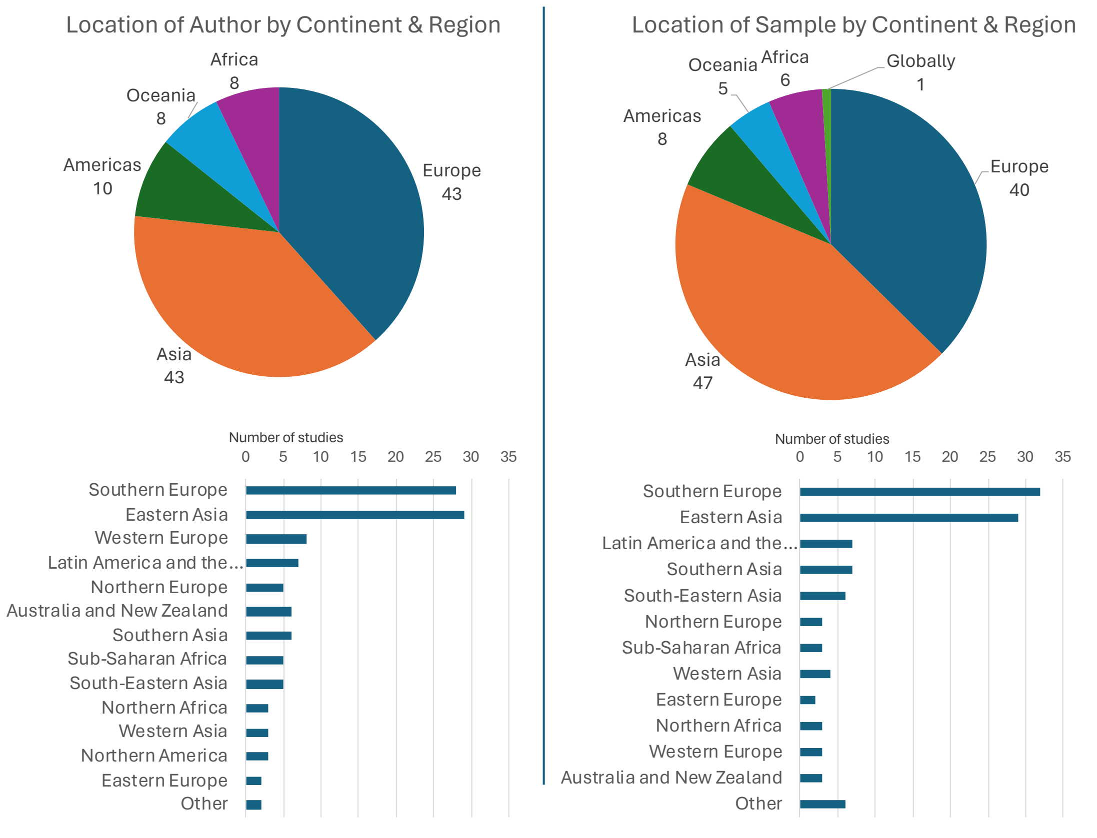


Figure 3: Author and Sample Location
Source: Author's own data

Regarding the locations of the analyzed sample, a similar pattern as with the authorship is found. Moreover, only around 5% (5 out of the 117 articles) of the articles focused on a sample analyzing multiple countries or regions (Becken and McLennan, 2017; Bohdanowicz and Martinac, 2007; Filimonau et al., 2021; Lootvoet and Roddier-Quefelec, 2009; Planinc et al., 2014), whereas most of the articles studied a single country. The top examined regions are using samples from Southern Europe (32 articles) and Eastern Asia (29 articles). Interestingly, all other regions under investigation are below eight articles, revealing an uneven distribution in the geographical spread of studies. Furthermore, the location of the sample is often similar to the origin of the first author, i.e., revealing a close proximity to the subject of study and scientific institution.

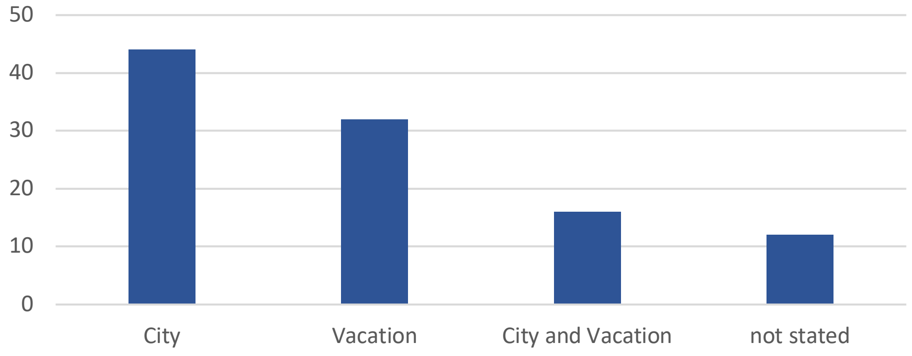


Figure 4: Hotel Operating Concept Analysis
Source: Author's own data

Regarding the location and associated hotel type (City or Countryside concept), the analysis discovered a preference towards urban areas or city hotels, respectively (42% of total articles) (Figure 4). Around a third of the articles analyzed rural/coastal locations or countryside types of hotels, and around 15% combined rural and urban destinations. Typically, countryside hotels provide different additional sub-facilities (e.g., swimming pool, irrigational gardens, meetings, incentive, conference, exhibition area (MICE area), gym) to guests and thus consume more resources (Bohdanowicz and Martinac, 2007; Deyà Tortella and Tirado, 2011). City hotels are generally associated with urban destinations, less service-intensive outlets and smaller room sizes. About 12% of the studies did not reveal any location information, making it harder to interpret findings as resource consumption is strongly associated with location and/or hotel operating concept (Bohdanowicz and Martinac, 2007; Huang et al., 2015; Santiago, 2021).

2.3.4. Sample Hotel Quality Level and Size

Despite location aspects, several authors argued that resource consumption is strongly correlated to the quality level of the hotels (Priyadarsini et al., 2009; Xuchao et al., 2010). As shown in Figure 5, the analyzed data set often comprises hotels operating on different quality levels according to their star-rating.[4] Studies examining the same quality level are

[4] Hotel star ratings serve as a widely recognized classification system used to indicate the quality and range of services offered by a property. These ratings, typically ranging from one to five stars, are based on standardized criteria such as room amenities, service offerings, dining options, recreational facilities, and overall guest experience (Min et al., 2002).

rare, with only four in the 3-star segment, 12 in the four-star segment as well as 13 in the luxury segment. Studies covering various quality levels are predominantly found within the 4-star (43 studies) and 5-star (41 studies) categories. Additionally, some studies specifically distinguish the collected data based on the quality level of hotels in relation to energy and water resource consumption. Therefore, it can be concluded that prior research on this topic tends to focus more on high-quality properties rather than those with lower star ratings.

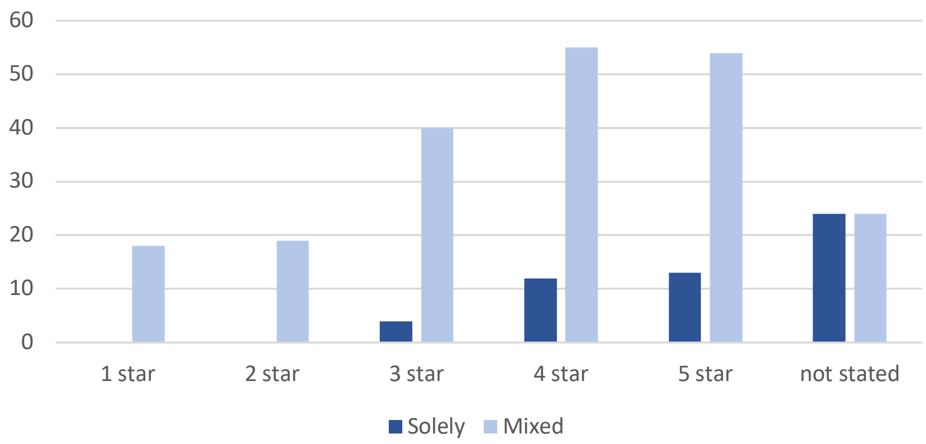


Figure 5: Quality Level of Hotels under Investigation
Source: Author's own data

As illustrated in Figure 6, most studies (77%) analyzed a sample below 50 hotels, which can be generally evaluated as satisfactory in terms of sample saturation (Saunders et al., 2012). Larger samples were usually found in quantitative studies where data was extracted from an external data set (Alkhalaf and Yan, 2018; Becken and McLennan, 2017; Bohdanowicz and Martinac, 2007).

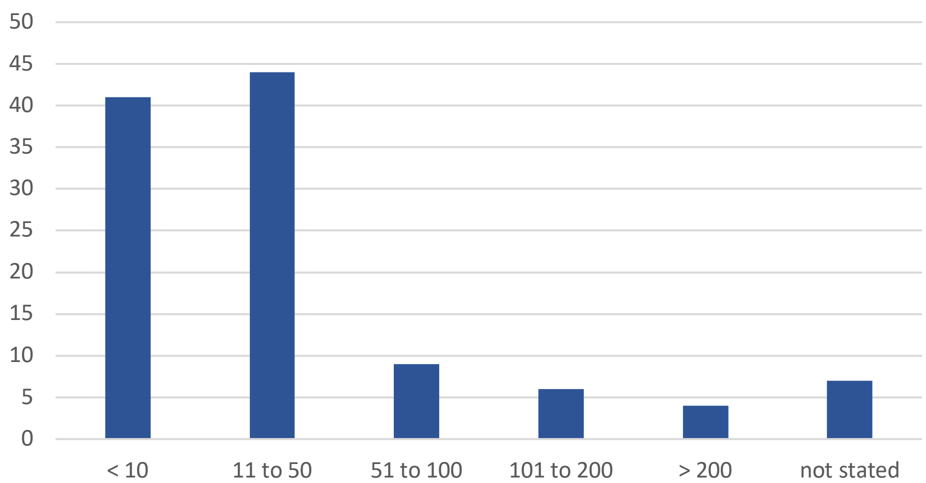


Figure 6: Sample Size
Source: Author's own data

While the overall average sample size across the reviewed studies is 51 hotels, notable differences emerge when analyzing the primary focus of each study. Research on water consumption reports an average sample size of 56 hotels, whereas energy-related studies average 49 hotels. In contrast, studies focusing on the measurement of greenhouse gas (GHG) emissions involve a considerably smaller average sample size of 17 hotels, which may be due to the complexity and methodological challenges associated with GHG data collection and reporting (UNWTO, 2023). Waste-related emissions auditing was predominantly performed with single-case studies or below five hotels. The largest study in this research field was executed by Pham Phu et al. (2018) analyzing solid waste of 120 hotels in Vietnam.

2.3.5. Used Research Methodology

	Frequency (*n*)	in %
Research Type		
Quantitative	76	65.0
Qualitative	26	22.2
Mixed	13	11.1
Not stated	2	1.7
Statistical Analysis*		
Descriptive Analysis	53	44.9
Linear Regression Analysis	17	14.4
Multiple Regression Analysis	26	22.0
Correlation Analysis	6	5.1
Variance of (co)variance (e.g. ANOVA)	6	5.1
t-test	1	0.8
Content Analysis	1	0.8
Data Envelopment Analysis (DEA)	2	1.7
Chi-square Analysis	1	0.8
Cluster Analysis	1	0.8
Delphi Analysis	1	0.8
Other	3	2.5

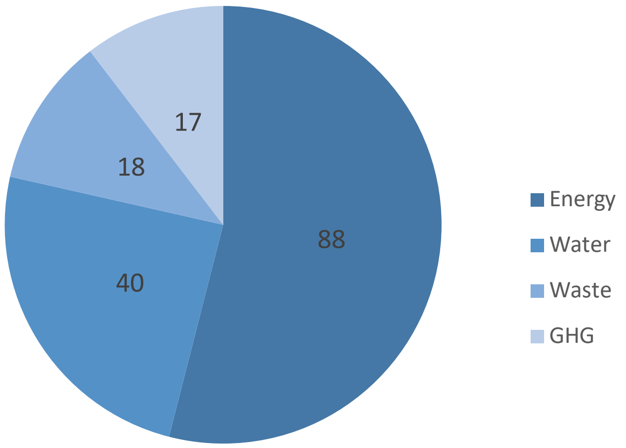
*multiple counts possible

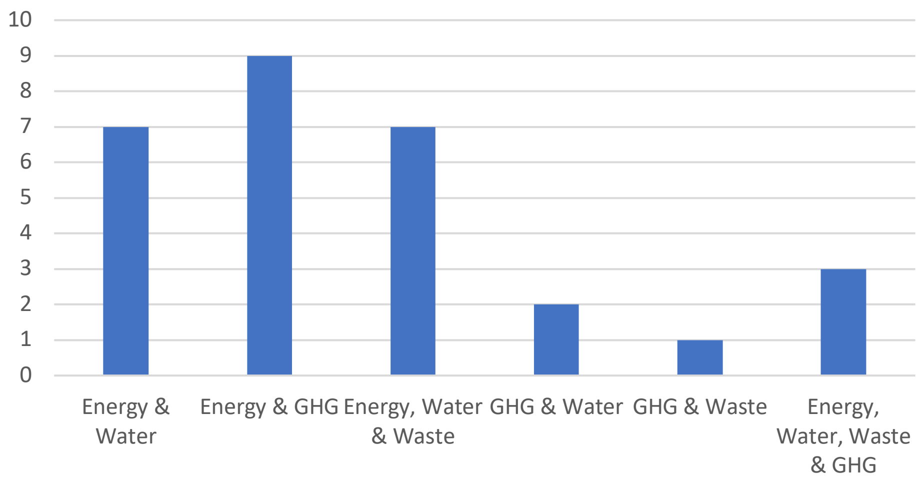
Table 5: Descriptive Analysis by Research Methodology
Source: Author's own data

The research type and statistical analysis of the selected articles are displayed in Table 5. The collection of data was predominantly done by questionnaire-based quantitative research methods (67% of the total sample). Most of the studies were collecting information about structural building characteristics (e.g., building age, floor area, number of rooms) and operational data (e.g., occupancy level, outlet characteristics) as well as associated resource consumption statistics (e.g., electricity and fuel use, water consumption). In a publication where a single-case was studied, often semi-structured interviews with lead management and technical staff were done in order to complete data collection (Debnath, 2015; Karagiorgas et al., 2007; Scholz et al., 2020). Some studies applied both techniques in a mixed research type by first asking for generic data from the real estate and operation via a questionnaire as well as complementing information by (semi-structured) interviews (Camilleri-Fenech et al., 2020; Huang et al., 2015; Lai, 2016; Ruiz et al., 2021; Tang et al., 2016). Regarding the statistical analysis of the data, there is a tendency to use descriptive analysis (45% of the total sample) exploiting results from distribution models, using medians and percentiles. Linear and multiple regression analyses are used to calculate the regression coefficients of significant factors affecting the resource consumption of hotel real estate. Furthermore, linear regression models are used to predict resource consumption. Different authors frequently use hybrid models by mixing descriptive and regression analysis. Other statistical analyses, such as testing the variance of (co)variance (Becken et al., 2001; Bhochhibhoya et al., 2020; Dinarès and Saurí, 2015; Hui and Wong, 2010; Pieri et al., 2015; Priyadarsini et al., 2009), were used less frequently.

2.3.6. Focus Areas and Intersections

When analyzing the topology of the paper (see Figure 7), it becomes evident that the majority of papers (*n=88*) focused on energy consumption, followed by water consumption (*n=40*). Studies relating to waste management (*n=18*) as well as GHG consumption are less frequent (*n=17*). Notably, some studies examine multiple environmental factors simultaneously, with a particular focus on energy and water (*n=8*), energy and GHG emissions (*n=9*), and a combination of energy, water, and waste consumption (*n=8*). Other combinations are explored less often. Comprehensive studies assessing all four environmental aspects remain relatively rare (*n=3*) but have gained traction in recent years (Duric and Potočnik Topler, 2021; Michailidou et al., 2015; Scholz et al., 2020).





Please note: Multiple counts are possible when the respective paper is focusing on two or more research fields

Figure 7: Typology of Papers by Research Field
Source: Author's own data

2.4. Critical Content Analysis: Metrics, Inputs, and Determinants

A hotel building is a complex operational environment that relies on a wide range of resources to support its various departmental services, including accommodation, F&B outlets, housekeeping, wellness, and administration. When it comes to the collection and measurement of data, scholars highlight the importance of testing and validating the practical viability of methods using hotels with different operational concepts as empirical case studies (Filimonau et al., 2011). However, several authors reported substantial difficulties in primary data collection of environmental performance in hotel real estate (Filimonau et al., 2011; Lai et al., 2012; Oluseyi et al., 2016). Furthermore, it is not yet common practice for most hotel owners to monitor their resource consumption (Pieri et al., 2015). Due to the specific characteristics of hotel real estate, dependent and independent variables affecting resource consumption must be evaluated (Warnkenet al., 2004). To shed light on variables and influencing factors, the 117 papers were divided into four main discussion topics and will be presented in the following section. The categorization derived from other similar studies such as Qi et al. (2017) or Warnken et al. (2004):

- Challenges in Environmental Metrics and Benchmarking (Chapter 2.4.1)
- Resource Consumption Inputs (Chapter 2.4.2)
- Generating Environmental Indicators (Chapter 2.4.3)
- Determinants of Resource Consumption (Chapter 2.4.4)
- Resource Audit Results (Chapter 2.4.5)

2.4.1. Challenges in Environmental Metrics and Benchmarking

Due to its distinct characteristics, such as diverse operation methods, seasonal demand variations, and high customer expectations, the hospitality sector encounters unique complexities in implementing environmental sustainability metrics and benchmarking. Generally, it is agreed that sustainability metrics and benchmarking are essential for assessing and improving environmental performance across the hotel industry (Bohdanowicz, 2006). However, several general challenges and issues were identified within the previous academic literature conducted and must be addressed to ensure their effectiveness and reliability.

One of the primary issues in environmental sustainability metrics is the absence of universally accepted standards, i.e., there is no consensus on reporting resource consumption in the hotel industry. Therefore, different organizations use varying methodologies and unreliable measurements, making comparing results across geographical regions difficult (Legrand et al., 2013). The lack of standardization in data collection and reporting frameworks leads to inconsistencies and reduced credibility in sustainability assessments (Jones et al., 2014). The study by Franzoni and Avellino (2019) argues that measurable indicators within the non-financial reporting of large hotel chains are close to nonexistent. What is more, it is found that non-financial reporting from large hotel chains do not use the same measurement units for reporting, making comparisons nearly impossible (Legrand et al., 2013). For example, Legrand et al. (2013) found that the energy intensity of six hotel chains are reported in six different metrics kWh per floor area, MJ per floor area, kWh per available room, MWh per available room, MJ per guest night, and in kgCO_2e per guest night. This may be because different countries and regions have varying regulatory requirements and multiple jurisdictions for environmental sustainability reporting. Furthermore, the absence of rigorous third-party verification exacerbates this problem, reducing trust in reported data and metrics (Font et al., 2023). As a result, companies may manipulate sustainability data to present a more favorable image, a practice known as greenwashing (Majeed and Kim, 2023). This can occur through selective disclosure, cherry-picking of favorable metrics, or misrepresenting sustainability initiatives (Alyahia et al., 2024).

Another issue identified is the standard financial reporting practices of the hotel industry. As Lau et al. (2021) elaborate, the reporting format commonly used in the hotel industry, USALI, typically presents results focused solely on costs, without incorporating key sustainability metrics or industry-standard value comparisons. In this light, authors such as Gössling and Lund-Durlacher (2021) recommended to foster the development of a framework for the collection and analysis of detailed data on energy use and emissions in the accommodation sector. During the 1990s, the first calls were made to perform environmental management and audits (Dale and Kluga, 1992; Kirk, 1995). Therefore, simple calculations to benchmark predominantly energy resources by using averages, medians, and rankings were executed to determine environmental efficiency (Santamouris et al., 1996; Zmeureanu et al., 1994). Measuring energy use, water consumption, and waste creation is well documented in academia and practice (Farrou et al., 2012). However, several authors stressed that metrics are often misunderstood by hotel operations (Coles et al., 2016; Font, 2012).

The lack of consistent data material as well as the frequent lack of sustainability indicators described by authors such as Dimler et al. (2018) or Planinc et al. (2014) demand for an easy-to-implement sector-specific solution for the collection of information and its meaningful analysis. In this context the study of Agyeiwaah et al. (2017, p. 26) stressed that "*so many indicators have been developed that industry seems to be overwhelmed by choice, leading to inaction, poor decision-making or adoption of the easiest option*". A recent study by the UNWTO (2023) reports that only 20.7% of 1,139 surveyed tourism enterprises actively measure their environmental performance. The findings indicate that particularly small and medium-sized enterprises (SMEs) face inherent challenges in measuring emissions and often struggle to identify a clear starting point for initiating decarbonization efforts. Similar results were concluded in the study of Alhudaithi et al. (2022), stating that there is no simple and robust procedure to estimate minimum water consumption based on specific hotel characteristics for benchmarking purposes. Therefore, authors claim that benchmarking efforts often fail to account for sector-specific, regional, or operational differences. Within the academic setting, it is stressed that researchers tend to depend on subjective judgments with no reference to any standards or criteria-supported measurement (Beccali et al., 2009) and rely mostly on ambiguous statements rather than specific metrics and indicators (Ruiz et al., 2021).

Another challenge identified is the high cost of investing in sustainability initiatives and reporting mechanisms, which can be especially burdensome for businesses with limited financial resources. It is highlighted that decision-makers must navigate the trade-off between short-term profitability and long-term environmental objectives, with managers often prioritizing immediate profitability over sustainable value creation (Haessler, 2020). While advancements in digital technology, such as big data analytics and artificial intelligence, offer opportunities for improved sustainability metrics, many organizations still rely on outdated systems (García-López et al., 2025). Additionally, the economic benefits of sustainability improvements are not always immediately apparent, leading to reluctance in adopting comprehensive sustainability benchmarking systems (Ekins and Zenghelis, 2021).

2.4.2. Resource Consumption Inputs

In terms of energy, the majority of resources come from electricity, which is generally used for air-conditioning, heating, lighting, escalators, and miscellaneous items such as kitchen equipment. Electricity consumption is generally the dominant source of carbon emissions in hotels (Beccali et al., 2009; Lai, 2015; Santiago, 2021).

Source	Year	Research Method	Sample Size	Location of sample	Electricity in %	Quality level of sample hotels	City / Vacation Hotel	Climate Region
Santiago, D.E.	2021	Quantitative	6	Spain	80	2, 3, 4, 5	Vacation	Temperate
Cunha, F.O., Oliveira, A.C.	2020	Qualitative	1	Portugal	81	4 star	Vacation	Temperate
Yao, Z., Zhuang, Z., Gu, W.	2015	Mixed	45	China	75	3, 4, 5	City	Dry
Lu, S., Wei, S., Zhang, K., Kong, X., Wu, W.	2013	Quantitative	27	China	83	4, 5	City	Dry
Wang, J.C.	2012	Quantitative	200	Taiwan	84	1, 2, 3, 4, 5	City and Vacation	Temperate
Udawatta L., Perera A., Witharana S.	2010	Qualitative	1	Sri Lanka	68	5 star	Vacation	Temperate
Xuchao W., Priyadarsini R., Siew Eang L.	2010	Quantitative	29	Singapore	91	3, 4, 5	City	Tropical
Beccali, M., La Gennusa, M., Lo Coco, L., Rizzo, G.	2009	Quantitative	4	Italy	90	1, 2, 3, 4, 5	City and Vacation	Temperate
Priyadarsini, R., Xuchao, W., Eang, L.S.	2009	Quantitative	29	Singapore	77	3, 4, 5	City	Tropical
Bohdanowicz, P., Martinac, I.	2007	Quantitative	184	Europe	49	3, 4	City and Vacation	Various
Onut, S; Soner, S	2006	Quantitative	32	Turkey	86	5 star	City	Temperate
Trung, D.N., Kumar, S.	2005	Quantitative	37	Vietnam	85	3 star	City and Vacation	Temperate
Chan K.T., Lee R.H.K., Burnett J.	2003	Quantitative	26	Hong Kong	72	3, 4, 5	City	Tropical
Deng, SM	2003	Quantitative	36	Hong Kong	68	4 star	City	Tropical
Shiming, D., Burnett, J.	2002	Quantitative	16	Hong Kong	73	3, 4, 5	City	Tropical
Becken, S., Frampton, C., Simmons, D.	2001	Quantitative	30	New Zealand	71	Not stated	City and Vacation	Dry
Deng, S.-M., Burnett, J.	2000	Quantitative	16	Hong Kong	73	3, 4, 5	City	Tropical

Table 6: Electricity in % of Total Energy Use
Source: Author's own data

Other energy sources than electricity typically play a minor role in the hotel industry (Önüt and Soner, 2006). The electricity share in hotels varies according to hotel location, classification, infrastructure, and concept but is generally around 80% of total energy use (city hotel 78%, countryside hotel 76%, see Table 6). Though, in the study of Díaz Pérez et al. (2019) it was found that close to 90% of operational GHG emissions come from electricity emissions. When it comes to water-related resource consumption, the study of Prakash et al. (2022) highlighted effective water management as the most crucial factor when preserving the environment. Likewise, Gössling et al. (2012) underlines the importance of performing water consumption audits with the same rigor as with energy and emission auditing. Furthermore, research revealed that it is generally far higher than household consumption due to water-intensive outlets (e.g., watering of gardens, swimming pools, laundry), higher standard accommodation as well as a 'pleasure' approach of the clientele subsequently using more water than usually (Lootvoet and Roddier-Quefelec, 2009), leading to pressure where water resources are scarce (Gössling et al., 2012). Likewise, this is also evident within waste figures (Camilleri-Fenech et al., 2020) particularly given due to the quantities of consumer goods used by hotels (Arbulú et al., 2015). A recent study of Filimonau et al. (2021) found that operational waste accounts for 34% of total GHG emissions of hotels, highlighting that waste treatment is hugely important when accounting operational impacts. Nevertheless, studies relating to waste management are still limited (18 studies in the sample).

Likewise to developments in energy consumption, scholars gradually respond to explore cause and effects of GHG emissions, identify the most cost-effective methods for assessments (De Grosbois and Fennell, 2011) and examine approaches for mitigation (Michailidou et al., 2015). Despite the academic interest, there is still no universal method present to measure firms' carbon footprint (European Commission, 2011) in general and within hotel operations specifically (Filimonau, 2016; Salehi et al., 2021) hindering cross-boundary and cross-sectoral comparisons as well as affecting the accuracy of audits (Schianetz et al., 2007). For example, a recent study by Deloitte shows that only 12% of all hotels in Austria measure their CO_2 footprint (Kapferer and Breyner, 2023). Nevertheless, scholars argue that with 90% of total emissions, GHG emissions are closely related to electricity consumption (Huang et al., 2015). Corporate GHG emissions accounting and reporting defines three "scopes", whereas Scope 1 accounts for direct GHG emissions that a company creates directly from its facilities (e.g., heating, vehicle fleet, generator). Scope 2 is predominantly bought electricity and, therefore, indirect GHG emissions. In the last category, all other indirect GHG emissions due to the company's activities up and down the supply chain are listed[5] (UNWTO, 2023). For example, within a hotel case, emissions from combustion of gas and diesel in cooking facilities or boilers account in Scope 1, purchased electricity in Scope 2, the guest journey as well as external laundry facilities in Scope 3 (Lai, 2015; Xuchao et al., 2010).

2.4.3. Generating Environmental Indicators

Deriving from a general definition, indicators are variables that make a phenomenon perceptible by conveying, quantifying, and monitoring essential information in a simplified manner (Nesticò and Maselli, 2020). Data selection is typically guided by robustness, frequency, availability, and adaptability. Robust data ensures accuracy, frequency affects relevance, availability determines accessibility, and adaptability allows for flexible application (Kurniawan et al., 2019; Tanguay et al., 2013). Additionally, the ability to quantify and ensure measurable outcomes, along with the practical feasibility of integrating this into daily operations, plays a crucial role (Karnauskaitė et al., 2019). When it comes to tourism-related indicators, several authors highlight the multiple components of the tourism system that must be taken into account (Agyeiwaah et al., 2017; Asmelash and Kumar, 2019). Subsequently, as outlined by Roberts and Tribe (2008) to generate valid and meaningful indicators, it is essential to define evaluation criteria as they vary inadvertently with the research objectives. In light of the above-mentioned exclusion criteria, while selecting articles, this paper classifies and ranks environmental indicators for the hotel industry based on the following criteria (adapted from Nesticò and Maselli (2020) and Sustainable Hospitality Alliance (2020)):

- *Goal*, according to the specific objective of the study
- *Relevance*, identify indicators applicable to the hotel industry
- *Frequency*, repeatedly mentioned in the available literature
- *Data availability*, evaluating accessibility
- *Operation*, implementation in the day-to-day business
- *Quantification capacity*, indicators must be quantifiable

Due to the aim and objective of this research, all analyzed previous studies developed intensity indicators. An intensity indicator can be defined as a unit that measures resource consumption (resource input) in relation to the specific level of service provision (reference unit) within the company (Duric and Potočnik Topler, 2021). Both relate to a

[5] Further information about the Scope 3 in the tourism related field can be found in Annex 3 of the UNWTO Climate Action in the Tourism Sector Report (UNWTO, 2023) or in the Technical Guidance to Calculate Scope 3 emissions (Barrow et al., 2013)

specific time frame (e.g., day, month, or year) and the corresponding resource unit (e.g., kWh for energy, liters for water).

$$intensity\ indicator = \frac{total\ input\ of\ used\ resources\ per\ unit\ and\ time}{reference\ value\ per\ time\ unit}$$

With regards to the hotel industry perspective, input measures are commonly referred to kind of resource (e.g., electricity and natural gas in energy matters). Reference units may be used using building industry benchmarks (e.g., per floor area), specifically tailored to the hotel industry (e.g., number of guests accommodated, number of rooms or beds) or individualized for specific outlets of the hotel (e.g., laundry consumption expressed in kg per linen, in restaurant number of meals served) (De Burgos-Jiménez et al., 2002).

In the course of the SLR, all intensity metrics referenced in the selected studies were systematically extracted, quantified, and consolidated to present a comprehensive summary of their application within the field. The identified intensity metrics are introduced in the following section, while a final summary is provided in the discussion section for comparative analysis (see Table 12).

2.4.3.1. Energy Intensity Indicators

Regarding energy-related intensity metrics, all input variables refer to adding up primary and secondary energy sources to ultimately gain the energy consumption of a respective hotel building. Therefore, the energy consumption (Q) of a hotel is usually calculated using the following formula adding annual consumption of electricity (Qe), chilled water (Qc), hot water (Qh), steam (Qs), diesel oil (Qd), gasoline (Qg) and natural gas (Qn) respectively (Sheng et al., 2018):

$$Q = Q_e + Q_c + Q_h + Q_s + Q_d + Q_g + Q_n$$

The energy use intensity (EUI) or average energy use index, defined in units of resource use per gross floor area per annum (kWh/m^2/annum), is usually used as the energy consumption indicator of the hotel industry.

$$Energy\ use\ intensity\ (EUI) = \frac{primary\ energy\ consumption}{total\ floor\ area\ (in\ m2)}$$

This indicator is found most dominant in this research field and was analyzed and audited by numerous authors (69 counts in previous studies, thereof 46 audits). Quantification and auditing of different hotel properties started in the early 90ies (Lam and Chan, 1994;

Zmeureanu et al., 1994) and has a long track record until today. While the indicator is easy to use, others stress that due to the complexity of the hotel real estate, it is not sufficient as a sole indicator to determine energy efficiency (Deng and Burnett, 2000; Karagiorgas et al., 2007). Furthermore, the authors stress that the EUI is not satisfactory for the highly fragmented asset class of hotels (Kim and Oldham, 2017; Qi et al., 2017; Teng et al., 2017) and needs to be normalized for other secondary drivers (Bohdanowicz and Martinac, 2007). Dibene-Arriola et al. (2021) found that EUI can serve as a starting point, and further indicators may be developed. Therefore, Chan (2005) highlighted to ascertain zonal EUIs to specific outlets of the hotel to illustrate the energy profile of a building with mixed functions. This approach was further developed by Karagiorgas et al. (2007), who differentiated the energy intake (fuel and electricity), cost centers, and end-use services/hotel outlets to ultimately display the energy flow through. The second group of indicators suggests using the energy consumption per production unit, defined as the ratio between energy consumption and an operational reference unit. Several scholars argued that this approach is better tailored to the asset class under investigation (Deng, 2003; Karagiorgas et al., 2007). The most prominent one within the energy segment is energy use per guest night (per day), which has been mentioned 19 times and thereof audited 15 times in the previous literature.

$$Energy\ use\ per\ guest\ night\ (EUPGN) = \frac{primary\ energy\ consumption}{total\ guest\ nights}$$

Less frequently used indicators are energy use per occupied room (mentioned 10 times and audited 5 times), energy use per room per year (mentioned 9 times and audited 6 times), and energy use per bed per year (mentioned 4 times and audited 1 time).

$$Energy\ use\ per\ occupied\ room\ (EUPOR) = \frac{primary\ energy\ consumption}{occupied\ rooms}$$

$$Energy\ use\ per\ room\ per\ year (EUPAR) = \frac{primary\ energy\ consumption}{available\ rooms}$$

$$Energy\ use\ per\ bed\ per\ year\ (EUPAB) = \frac{primary\ energy\ consumption}{available\ beds}$$

2.4.3.2. Water Intensity Indicators

When it comes to water-related metrics, input variables are generally referring to the collection of total water withdrawal. The vast majority of measuring water consumption (31 counts, thereof 26 audits) was done by listing the liter per guest night (WUGN). Others used the reference unit total floor area per year (water use intensity, WUI, 9 counts, thereof 8 audits), occupied rooms (WUOR, 5 counts, thereof 3 audits), or total floor area per day (WUId, 7 counts, thereof 2 audits). Several scholars highlight to differentiate whether the hotel possesses an in-house laundry (Bohdanowicz and Martinac, 2007; Deng, 2003; Ricaurte, 2011) the kg laundry per guest night (LGN) is increasingly important (3 counts, thereof 1 audit). It must be acknowledged that the indicators generally only measure direct water use, ignoring grey water, recycled water, or the importance of embodied water use (e.g., food procurement, fuels) (Gössling, 2015). Furthermore, it is argued that more comprehensive indicators must be implemented by splitting according to hotel outlets, area of irrigated garden per room/bed, and area of pool per room/bed (Gössling, 2015). WUOR and WUGN are as well part of the agreed intensity metrics by the Hotel Water Measurement Initiative (HWMI) (Sustainable Hospitality Alliance, 2020).

$$Water\ use\ per\ guest\ night\ (WUGN) = \frac{water\ consumption\ in\ liter}{total\ guest\ nights}$$

$$Water\ use\ intensity\ (WUI)\ per\ year = \frac{water\ consumption\ per\ year\ in\ liter}{total\ floor\ area\ (in\ m2)}$$

$$Water\ use\ per\ occupied\ room\ (WUOR) = \frac{water\ consumption\ in\ liter}{occupied\ rooms}$$

$$Water\ use\ intensity\ (WUId)\ per\ day = \frac{water\ consumption\ per\ day\ in\ liter}{total\ floor\ area\ (in\ m2)}$$

$$Laundry\ in\ kg\ per\ guest\ night\ (LGN) = \frac{total\ laundry\ washed\ in\ kg}{total\ guest\ nights}$$

2.4.3.3. Waste Intensity Indicators

Regarding waste management practices, there is presently no international standard format for waste audits which hinders possibilities for comparison between different studies (Camilleri-Fenech et al., 2020). Pirani and Arafat (2016) provide a comprehensive review of different waste management practices within the hospitality industry. The study focused on solid waste and suggests performing waste mapping to further understand the type, quantity, and location of waste generation and recommends reduction measurements. Furthermore, Juvan et al. (2023) discovered that biodegradable waste accounts for two-thirds of the waste generated in restaurants, whereas in hotels, it comprises only one-third. Others, such as Diaz-Farina et al. (2023), established a progressive Pay-as-you-throw penalty system to incentivize waste separation. The model was based on an intensity indicator, defined as the ratio between waste flows and property size. Associated indicators to waste management are generally either proposing kilograms or liter as measurement scale with kg per person per day being the most prominent. This may be either done for the whole hotel (Ball and Taleb, 2011; Camilleri-Fenech et al., 2020; Debnath, 2015) or by outlet such as Food&Beverage (F&B) in general (Papargyropoulou et al., 2016) or in specific parts (e.g., buffet breakfast leftovers in Leverenz et al. (2021)). Nevertheless, input measures for waste benchmarking remain blurred. Indicators found are generally counting solid waste figures divided by the waste producer, i.e., guest or consumer. The following intensity indicators are revealed in waste management:

$$Waste\ in\ kg\ per\ guest\ (WkgPG)\ =\frac{solid\ waste\ generated\ in\ kg}{guests}$$

$$Waste\ in\ kg\ per\ guest\ night\ (WkgPGN)\ =\frac{solid\ waste\ generated\ in\ kg}{guest\ nights}$$

$$Waste\ in\ liter\ per\ guest\ per\ day\ (WlPG)\ =\frac{solid\ waste\ generated\ in\ liter}{guests}$$

$$Waste\ in\ kg\ intensity\ (WkgI)\ =\frac{solid\ waste\ generated\ in\ kg}{floor\ area}$$

$$Waste\ in\ liter\ per\ guest\ per\ day\ (WlPG)\ =\frac{solid\ waste\ generated\ in\ liter}{guests}$$

2.4.3.4. GHG Emissions Intensity Indicators

There are several methods to assess the environmental or carbon footprint of hotels in the academic and non-academic literature. Studies related to GHG emissions are generally calculated through a Life Cycle Assessment Approach (LCA) (Filimonau et al., 2021; Hu et al., 2015; Salehi et al., 2021; Michailidou et al., 2015), Environmental composite indicator/index (ECI) (Michailidou et al., 2015; Teng et al., 2012), or Ecological Footprint Analysis (EFA) (Castellani and Sala, 2012; Chen and Hsieh, 2011). While Castellani and Sala (2012) concluded that the lack of data hampered specific results, Chen and Hsieh (2011) found that energy use and food consumption accounted for over 90% of the environmental footprint of the studied hotels. Due to problems with data availability as well as accessibility, scholars focus on specific stages of the business lifecycle. Studies relating to the operational phase are diverse with different calculation formats (Hu et al., 2015; Huang et al., 2015; Puig et al., 2017; Rico et al., 2019). Based on their findings, Filimonau et al. (2011) proposed the establishment of system boundaries, recommending that studies focus on collecting primary data related to operational energy use. In contrast, non-operational GHG emissions, such as those from food procurement, furniture, and equipment, should either be estimated at 15% or excluded from analysis entirely due to limited data availability (Salehi et al., 2021). Furthermore, several authors excluded staff and guest travel and associated carbon footprint from their analysis (Filimonau, 2016; Filimonau et al., 2021). Indirect and non-operational impacts were first discussed by Filimonau et al. (2021) and found that around 25% of total GHG emissions are related to hotel building construction.

Different authors found that the contribution of water use and wastewater treatment to the overall GHG emissions is marginal and can, therefore, be excluded from the environmental assessment of GHG emissions (Díaz Pérez et al., 2019; Filimonau et al., 2021; Hu et al., 2015). As a result, measuring and displaying the associated GHG emissions is a complex process. CO_2-equivalent ($kgCO_2e$) is the common unit of measurement to indicate the global warming potential of each of the six greenhouse gases covered by the Kyoto Protocol (World Business Council for Sustainable Development, 2005). What is more, previous studies often lack the application of credible and internationally recognized standards—such as the Greenhouse Gas Protocol, PAS 2050, or ISO/TS 14067—for calculating the carbon footprints of hotels (Hu et al., 2015). Furthermore, results were generally limited to average values, usually ignoring influencing factors (Tsai et al., 2014). Although studies related to GHG consumption are still rare, several intensity indicators could be identified.

$$Carbon\ emission\ per\ guest\ night\ (COPGN) = \frac{kgCO_2e}{guest\ nights}$$

$$Carbon\ emission\ use\ intensity\ (COUI) = \frac{kgCO_2e}{floor\ area}$$

$$Carbon\ emission\ per\ available\ room\ (COPAR) = \frac{kgCO_2e}{available\ rooms}$$

$$Carbon\ emission\ per\ available\ bed\ (COPAB) = \frac{kgCO_2e}{available\ bed}$$

$$Carbon\ emission\ per\ occupied\ room\ (COPOR) = \frac{kgCO_2e}{occupied\ rooms}$$

Especially within recent studies applying the LCA approach, the functional unit of one guest night is frequently used (Filimonau et al., 2021; Salehi et al., 2021; Puig et al., 2017). Therefore, the most common one is $kgCO_2e$ per guest night (18 counts, thereof 12 audits) followed by $kgCO_2e$ per floor area (9 counts, thereof 6 audits). Other reference units can be identified as guest room per year (5 counts, thereof 4 audits) as well as per bed (1 count, thereof 1 audit) and occupied room (3 counts, thereof 3 audits).

2.4.4. Determinants of Resource Consumption

When defining a peer group to benchmark with, it is essential that the characteristics of the company and peers are similar (Kotsantonis and Serafeim, 2019). While Deng (2003) found no clear evidence of influencing variables in resource consumption, the majority underlines the importance of determining factors to accurately measure and interpret results (Mechri and Amara, 2021; Sheng et al., 2018). Chan (2009) further elaborated on the inappropriate use of indicators in Energy Management Systems without determining influencing factors. The degree of dependence was found in different ways – either as a result of resource audits and comparing them with the collected sample characteristics or by performing (multiple) stepwise linear regressions to test statistically significant variables against the resource component or indicators such as EUI. The usual practice is to collect a list of such potential 'drivers' of energy consumption from buildings, and then apply regression techniques to identify the statistically significant factors for normalization (Xuchao et al., 2010). Generally, indicators with a correlation $R^2 > 0.6$ and $R^2 > 0.8$ are considered as potential and strong potential indicators respectively (Becken et al., 2001; Bohdanowicz and Martinac, 2007; Cabello Eras et al., 2016; Deng, 2003).

Commonly factors influencing resource consumption are divided into physical and operational parameters (Bohdanowicz and Martinac, 2007; Cabello Eras et al., 2016; Trung and Kumar, 2005), others adding climate (Chan, 2009) and resource end-use factors (Lu et al., 2013). Deng and Burnett (2000) distinguished between guest-floors and non-guest floors (i.e., area except hotel rooms) and recommended to measure energy performance in guest-floors based on unit floor area, hotel class and occupancy level. Non-room areas are more complicated and should be treated separately with corresponding reference units. Bohdanowicz and Martinac (2007) highlighted the importance of clustering and differentiating characteristics to gain more precise resource consumption models. Likewise, within water consumption variables, physical and operational characteristics, as well as hotel occupancy, can be identified (Antonova et al., 2023; Gabarda-Mallorquí et al., 2017; Tirado et al., 2019). Furthermore, water-related units, i.e., all hotel facilities using extensive water resources, possess a strong influence on water consumption (Antonova et al., 2023; Gössling et al., 2012). Furthermore, evidence of the inter-relationship between energy, water, and waste and the opportunity for achieving tangible synergies from savings initiatives. In particular, savings in energy use seem strongly associated with savings in water use and vice versa (Becken and McLennan, 2017). The following chapters provide a comprehensive overview of key factors extensively examined in the literature, with a focus on their influence on resource consumption within hotel properties.

2.4.4.1. Operational Factors

Being a real estate with special characteristics and various operational concepts, several authors stressed the importance of differentiating by operational factors associated with the hotel concept (Bohdanowicz and Martinac, 2007; Tang et al., 2016; Teng et al., 2017). In terms of the relationship between energy use and occupancy level, the majority of studies found a low correlation (AlFaris et al., 2016; Kim and Oldham, 2017; Lai, 2016; Lu et al., 2013; Priyadarsini et al., 2009; Tang et al., 2016; Warnken et al., 2004; Yao et al., 2015; Lai, 2015; Xin et al., 2012; Chan and Lam, 2002; Lanka Udawatta et al., 2010; Nguyen and Rockwood, 2019). Shiming and Burnett (2002) and Bohdanowicz and Martinac (2007) concluded that the number of guests affects energy consumption. In contrast, other authors found a strong correlation between occupancy levels and energy consumption in their studies (Deng and Burnett, 2000; Wang, 2012). The third group of researchers found a trend toward the dependence between occupancy and energy consumption but had to declare it not relevant (Becken et al., 2001). In a study of 50 Australian hotels, it was found that with occupancy rates between 70% and 100% there is little effect on the energy consumption. Energy intensity drops off when occupancy decreases below 70% (AusInfo, 2002). A similar result was observed in the study of Eva et al. (2009). Interestingly, in the study of Santiago (2021) a high correlation between guest nights and energy consumption was found, but a low correlation with occupancy level was discovered. This may be because the mean number of guests per occupied room is different or caused by seasonality factors (Santiago, 2021). Therefore, it can be argued that at high occupancy levels, its influence on overall energy consumption is relatively limited (Priyadarsini et al., 2009). When it comes to associated GHG emissions in the study of Huang et al. (2015) a strong correlation with the occupancy level was revealed. Likewise, GHG emissions per guest night decrease when the occupancy level increases (Tsai et al., 2014).

In terms of water consumption, a correlation between guest nights sold (Bohdanowicz and Martinac, 2007) and occupancy (Barberán et al., 2013) was concluded. On the contrary, Antonova et al. (2023) found a strong negative correlation between both attributes. Alhudaithi et al. (2022) investigated the different outlets of a hotel and their water consumption. It is thus argued that the rooms, kitchen, and laundry are most dependent on the occupancy rate when it comes to water consumption. Irrigation of gardens and pools are concluded to have medium to low dependency. Lootvoet and Roddier-Quefelec (2009) concluded that higher occupancy rates in hotels reduce water consumption per guest per day. Therefore, Gössling et al. (2012) suggests a distinction between fixed and variable water use, the latter referring to water consumption in relation to occupancy levels. Others failed to reveal any meaningful correlation when analyzing occupancy rate and water consumption (Charara et al., 2011) or even denied a correlation at all (Deyà Tortella and Tirado, 2011). Nevertheless, the latter author identified a correlation between water consumption and the number of months a hotel operates, with each additional month of operation associated with an approximate 7% increase in total water usage. In this context, Gössling (2001) highlighted that strong seasonality in combination with arrival peaks during dry season might thus put considerable strain on available water resources. In the study of Alhudaithi et al. (2022) the hotel water consumption index (HCWI) was implemented considering operational and physical characteristics such as number of rooms, number of seats in restaurant, geographical location, garden area, swimming pool area, and occupancy rate.

Considering the quality level and the associated star rating of the hotel, the majority of studies concluded a high correlation with energy consumption, revealing that energy consumption increases the more luxurious a hotel gets (Nguyen and Rockwood, 2019; Priyadarsini et al., 2009; Xuchao et al., 2010; Yao et al., 2015; Qi et al., 2017). In the study of Deng and Burnett (2000), Wang (2012). and Santiago (2021) no clear correlation between quality level and energy consumption was found. Regarding the quality level of hotels and associated GHG emissions, authors such as Huang et al. (2015), Tsai et al. (2014) and Filimonau et al. (2021) postulated a significant correlation. This is generally in line with other authors discussing the relationship between hotel comfort level and its emission impact (Chen and Hsieh, 2011; Lai, 2015; Puig et al., 2017; Xuchao et al., 2010). Therefore, scholars generally agree that water consumption is directly and positively associated with the quality level of a hotel (Barberán et al., 2013; Dinarès and Saurí, 2015; Rico-Amoros et al., 2009; Deng and Burnett, 2002; Gössling et al., 2012). A further operational influencing factor is that, commonly, the numbers of employees are associated with the quality level of the hotel. Oluseyi et al. (2016), Tang et al. (2016), Wang (2012) and Santiago (2021) found a strong correlation between energy consumption and the number of workers. Similarly, Xuchao et al. (2010) initiated the indicator EUI worker density (number of workers on main shift per 1000 m^2 of GFA) and concluded a high correlation. On the contrary, in the study of Wang (2012) a correlation between energy consumption and the number of workers was denied. Charara et al. (2011) found the most influential variable of water consumption is the number of employees working in a hotel.

As previously discussed, the expansion of services and functional outlets within hotels is associated with increased resource consumption (Tsai et al., 2014). Santiago (2021) analyzed F&B services and found that the variables number of diners, number of meals, and recycled kitchen oil were highly correlated with energy consumption. A strong correlation between energy and water consumption and number of food covers was also found by Bohdanowicz and Martinac (2007), revealing that each food cover sold consumes an additional 6 liters of water. The same result was observed in direct (drinking water) and indirect (water use in kitchens for both cooking and washing) water consumption (Bohdanowicz and Martinac, 2007; Deng and Burnett, 2002; Deyà Tortella and Tirado, 2011). Furthermore, scholars agree that an in-house laundry has a significant influence on the energy and water consumption of a hotel property (Bohdanowicz and Martinac, 2007; Deng and Burnett, 2002) and should, therefore, be separately addressed (Deng, 2003). In hotels with extensive garden surfaces, around 50% of their water consumption is used for irrigation (Gössling, 2001). Likewise, Styles et al. (2015) concluded that around 50% of water consumption is used in public or collective areas. On the contrary, in the study of Alhudaithi et al. (2022) only 18% of water use was used for irrigation, rooms (35% of total water use) and Kitchen (21% of total water use) being the highest. Dimensions and water volume flows of F&B, MICE areas, as well as the amount of detached structures such as wellness pool facilities and water-intensity of landscaped ground are important for water consumption (Gössling et al., 2012; Gopalakrishnan and Cox, 2003; Warnken et al., 2005) and are therefore commonly associated with the range of facilities offered by the hotel (Charara et al., 2011).

On the contrary, spa facilities do not seem to have a significant effect on hotel water consumption (Bohdanowicz and Martinac, 2007; Deyà Tortella and Tirado, 2011). When analyzing the spa outlet, Bohdanowicz and Martinac (2007) suggested that the correlation factor would be higher when guests not staying at the hotel (so-called day-time guests) are integrated into the analysis. Furthermore, the study concluded that each square meter of landscaped ground area consumes an additional 8.8 liters of water per year. Best practices for different outlets were analyzed in the study of Styles et al. (2015), stating that water-saving measures generally possess a payback period of less than three years. Interestingly, the analysis of survey results of Deyà Tortella and Tirado (2011) revealed that neither the existence of a sustainability department nor severity of water regulation or water costs are influencing water consumption. When it comes to waste management practices and the influence of operational practices close to no evidence was found in the reviewed literature. The study of Ball and Taleb (2011) argued that factors affecting waste are more related to the number of rooms and occupancy percentage rather than hotel type, location, or affiliation.

When it comes to chain affiliation, so whether a hotel is part of an international hotel brand (e.g., Marriott International, Hilton Worldwide), literature generally argues that economies of scale are achieved (Ivanov et al., 2016). The regression model in the study of Deyà Tortella and Tirado (2011) analyzing water consumption of 196 hotels found that the effect depends on the chain's size. Whereas small chain hotels have an 18% lower water consumption than independent hotels, hotels being part of a large chain displayed a 34% higher water use than the independent hotels within the sample. On the contrary, the study of Iddawala et al. (2024) revealed that larger chains are generally more resource-efficient.

2.4.4.2. Physical Factors

Despite operational factors strongly associated with the service offered in a hotel, physical aspects of the real estate property are also relevant when it comes to resource consumption. Regarding the ground floor area (GFA) or hotel size, scholars generally found a strong correlation regarding energy consumption, arguing that consumption increases the larger the hotel gets (Becken et al., 2001; Bohdanowicz and Martinac, 2007; Santiago, 2021; Wang, 2012; Xuchao et al., 2010) and the more rooms it has (Santiago, 2021). Others, predominantly older studies, concluded a weak or no correlation (Deng and Burnett, 2000; Lam and Chan, 1994; Tang et al., 2016). On the contrary, when analyzing the EUI and floor area, it can be seen that EUI decreases when the hotel gets larger (Chan and Lam, 2002). Interestingly, in the study of Wang (2012) a strong correlation was found in the number of floors as well as average floor area per room, both explaining 91.6% of the annual variation of energy consumption. When it comes to GHG emissions, it is argued that GFA correlates positively, while the GHG emissions intensity per floor area decreases the larger a hotel is (Huang et al., 2015). A weak correlation was observed in the study of Wang (2012). Surprisingly, Tsai et al. (2014) found that GHG emissions per person per night rise together with the increasing physical size of hotel. Likewise to energy consumption, water demand is highly dependent on factors such as hotel size (Bohdanowicz and Martinac, 2007; Deyà Tortella and Tirado, 2011; Gopalakrishnan and Cox, 2003; Gössling et al., 2012). In the work of Deyà Tortella and

Tirado (2011) the relationship between number of rooms and water consumption is inverse. Although the structural characteristics of the building (e.g., wall insulation, ceiling system, electrical installations) and the resource end-use factors (e.g., equipment used for heating, cooling, hot water production, lighting) can have a significant impact on energy consumption, these are generally not considered due to a lack of data (Krstinić Nižić et al., 2017). Deng (2003) found that energy and water use data is significantly influenced by the type of boiler used (gas or non-gas) or electrical water heating. Moderate to high significance was found between the energy use and the number of repairs done by the facility management of the hotel real estate. Therefore, it was concluded by Santiago (2021) that building wear can influence energy demand. Nevertheless, in the study of Wang (2012) the difficulty of measuring renovations and their effects was highlighted.

Generally speaking, age and renovations could significantly impact the energy usage of hotels. By installing more efficient lighting or air-conditioning systems, energy consumption could potentially decrease by 20–40% without compromising hotel operations (Graci and Dodds, 2008). Some authors were researching the retrofit of buildings (Peng et al., 2012; Santamouris et al., 1996). In terms of age-related influencing factors in energy consumption, Warnken et al. (2005) noted that hotel businesses established before or during the early stages of ecotourism popularization generally possess low resource use efficiency when compared to more recently established, purpose-built eco-resorts. Wang (2012) noted that the EUI of newly constructed hotels is often lower than in older hotels. In the study of Deng and Burnett (2000) the age of the property revealed no significance in the energy consumption of the sample hotels. AlFaris et al. (2016) investigated 19 4- and 5-star hotel buildings in the United Arab Emirates and explicitly differentiated between building age pre- and post-2003. It was found that the EUI varies between 241.5 and 348.4 kWh/m^2/year for post-2003 and 348.4 and 511.1 kWh/m^2/year for pre-2003 hotels, revealing that younger hotels are generally more energy efficient. In the study of Nguyen and Rockwood (2019) analyzing 52 hotels in Vietnam no considerable correlation between energy use and building age was found. The study argued that there is even a tendency for newer buildings to consume more energy than older ones. Regarding water, waste or GHG consumption and the relation to age factors of the hotel building, no evidence in the reviewed literature was found. To summarize, profound studies related to age factors of the hotel building are blurred and no valid conclusions can be drawn.

2.4.4.3. Location and Climate

When benchmarking resource consumption, accounting for climatic variability is essential, as climate-related factors can significantly skew performance comparisons across different regions. Shiming and Burnett (2002) found that the mean outdoor temperature has four times more influence on resource consumption than the total number of guests. Moreover, most interviewees in the study of Chan (2012) agreed that climatic regions may exert the most significant demand on resource consumption. This is mainly evident in areas where tropical climate prevails, and excessive use of heating, ventilation, and air-conditioning systems (HVAC) is necessary (Lanka Udawatta et al., 2010; Yao et al., 2015). Furthermore, it is revealed that the air-conditioning remains on in tropical climate zones even though the room is not occupied (Lanka Udawatta et al., 2010; Priyadarsini et al., 2009). Therefore, to make results in resource consumption comparable in a global setting, scholars have already early called for a method to eliminate the effect of climatic conditions (Chan and Lam, 2002) or emphasize that the result may not be comparable in another geographic setting without normalization (Bohdanowicz and Martinac, 2007). Nevertheless, scholars highlight that studies on resource consumption are still not comparable due to missing climate-related factors (Cabello Eras et al., 2016). As a result, various models were developed to measure climate effects accurately. Some of the proposed models performed linear regressions correlating energy consumption with the outside air temperature which generated a positive correlation in previous studies (Lai, 2015; Priyadarsini et al., 2009), while others denied a correlation (Warnken et al., 2004). In the study of Priyadarsini et al. (2009) it was found that electricity consumption generally follows the changing outdoor temperatures, indicating that outdoor temperature explains a large proportion of the variation in energy consumption. A relevant parameter to take into account the influence of the outdoor temperature is the Cooling Degree Day (CDD) method, commonly defined as the sum of differences between outdoor air temperature and a reference temperature (Krese et al., 2012; Xin et al., 2012).

Others stress that weather normalization is generally unreliable due to other factors non-related to the weather such as hotel characteristics (Xuchao et al., 2010). In the study of Xin et al. (2012) the application of the degree day method was calculated by creating a climate adjustment coefficient out of the weather data multiplied by the respective EUI, resulting in EUInorm. Regarding outlets in hotels that need climate normalization, Ricaurte (2011) suggests that a normalization of in-house laundry should be done as a minimum to make results comparable. Furthermore, several studies found noticeable variation in the average EUIs not only across different climatic regions but also within climatically similar regions, highlighting the complexity of hotel real estate (Kim and

Oldham, 2017). In the study of Wang (2012) a location district variable was implemented, concluding that hotels located in well-developed regions (in this case, Taipei city) consume more energy than any other city in the same geographic region. The underlying reasons for this phenomenon are still vague and need further investigation. Cabello Eras et al. (2016) analyzed the energy consumption of two Cuban hotels and normalized weather data with the Weather Underground Database (McNally et al., 2015). The study introduced a modified version of the CDD method, incorporating the Room Degree Day (RDD), which is calculated by multiplying the CDD by the daily occupancy level. This approach generates a Daily Control Graph (DCG), enabling swift identification of inefficiencies and malpractices.

To summarize, while weather normalization techniques like degree day methods can enhance comparability in hotel energy use analysis, their reliability is often limited by non-weather-related variables such as hotel characteristics and location. These findings underscore the complexity of accurately normalizing energy data in the hospitality sector and highlight the need for more nuanced, location-specific, and operationally tailored approaches. Regarding the relationship between climate and water consumption, scholars have different opinions. While some found that water consumption is not highly dependent on climate (Bohdanowicz and Martinac, 2007; Shiming and Burnett, 2002), others postulate a strong dependency (Barberán et al., 2013; Mclennan et al., 2017). In the study of Antonova et al. (2023) investigating gardening and weather conditions on their water consumption the results were non-significant, however, a tendency towards higher temperature leads to higher water consumption. Regarding waste management and GHG emissions no studies were found related to climate adjustments.

A detailed overview of the climate distribution is provided in Table 7. The analyzed samples are predominantly located in the temperature climate zone ($n=39$), followed by tropical ($n=25$) and studies in dry regions ($n=14$). Studies focusing on continental climates are less common ($n=3$), and no studies are identified within polar regions. Additionally, only two studies offer cross-comparative analyses across multiple climate zones. This limited climatic scope restricts the generalizability of current findings and underscores the need for broader research coverage to better understand how varying climatic conditions influence resource performance in the hotel industry.

Climate Region	Count	in %
Total Sample*		
Temperate	39	47.0
Tropical	25	30.1
Dry	13	15.7
Continental	3	3.6
Polar	0	0.0
Various	3	3.6

Climate Region	Count	in %
Energy		
Temperate	17	36.2
Tropical	17	36.2
Dry	9	19.1
Continental	3	6.4
Polar	0	0.0
Various	1	2.1
Water		
Temperate	15	62.5
Tropical	4	16.7
Dry	3	12.5
Continental	0	0.0
Polar	0	0.0
Various	2	8.3

Climate Region	Count	in %
Waste		
Temperate	1	50.0
Tropical	1	50.0
Dry	0	0.0
Continental	0	0.0
Polar	0	0.0
Various	0	0.0
GHG		
Temperate	6	60.0
Tropical	3	30.0
Dry	1	10.0
Continental	0	0.0
Polar	0	0.0
Various	0	0.0

*was counted when resource audit was performed in the respective article

Table 7: Climate Zones of Samples
Source: Author's own data

2.4.5. Resource Audit Results

This section presents the SLR results of resource audits conducted across 84 studies, offering a systematic assessment of environmental performance in the hotel sector. "*Comparing a company's environmental performance should be done preferably with companies in the same sector with similar characteristics and at the same point in time*" (De Burgos-Jiménez et al., 2002, p. 217). In line with this principle, these studies rely on quantitative data to analyze resource consumption. To facilitate comparability in the audit analysis in Table 8 to Table 11, all formats are recalculated to a common numerical standard (e.g., MJ to kWh or feet to m^2). When several quality levels of hotels were being under investigation within the study a weighted average is formed. Furthermore, when more than one year was analyzed in the study, the mean of all years under investigation is presented. The climate zone is differentiated by the widely used Köppen Climate Classification System and was classified according to hotel location like in other studies (Bohdanowicz and Martinac, 2007; Huang et al., 2015).

The identified dominant intensity indicators are analyzed per area:

- Energy: Energy Use Intensity (EUI)
- Water: Liter per Guest Night (WUGN)
- Waste: Total Waste in kg per Person (WkgPG) or Guest Night (WkgGN)
- GHG: $kgCO_2e$ per Guest Night (COGN)

The following key influencing factors are distinguished where applicable:

- Hotel Classification/Star Rating (ranging from 1-star budget hotels to 5-star luxury hotels)
- Geographical Location (country where the sample is located)
- Climatic Zone (categorized as temperate, tropical, dry, continental, polar, or various)
- Hotel Concept (urban vs. rural hotels)

2.4.5.1. Energy Audit Analysis

By analyzing Table 8, it is found that the vast majority of studies analyzed city hotels (25 studies), followed by studies with a mixed focus (11 studies) and countryside hotels (5 studies). In general, the examined sample of 2,280 hotels, irrespective of climate, quality level, or location, exhibited an EUI of 273.9 kWh/m^2. A significant disparity in EUI metrics is evident across the studies, ranging from as high as 714 kWh/m^2 (Becken and McLennan, 2017) to as low as 91.2 kWh/m^2 (Teng et al., 2017). Regarding the operational concept, it is found that city hotels (EUI 305.9 kWh/m^2, 718 sample hotels) consume more energy than countryside hotels (EUI 218.8 kWh/m^2, 19 sample hotels). Though, it must be acknowledged that this number may be distorted due to the low number of sample hotels in the countryside hotels sample. Studies analyzing city and countryside hotels are in between (EUI 269.7 kWh/m^2, 1,543 sample hotels).

Source	Year	Research Method	Sample Size	Location of sample	Mean EUI (kWh/m2/year)		Quality level of sample hotels	City / Vacation Hotel	Climate Region
Becken, S., McLennan, C.	2017	Quantitative	821	Globally	714.0	*	1, 2, 3, 4, 5	City and Vacation	Various
Zmeureanu, R.G., Hanna, Z.A., Fazia, P.	1994	Quantitative	16	Canada	612.0		Not stated	Not stated	Temperate
Shiming, D., Burnett, J.	2002	Quantitative	16	Hong Kong	563.8		3, 4, 5	City	Tropical
Deng, S.-M., Burnett, J.	2000	Quantitative	16	Hong Kong	563.8		3, 4, 5	City	Tropical
Deng, SM	2003	Quantitative	36	Hong Kong	541.6		4 star	City	Tropical
Chan K.T., Lee R.H.K., Burnett J.	2003	Quantitative	26	Hong Kong	519.4		3, 4, 5	City	Tropical
Prasad, K; Singh, A	2015	Quantitative	2	Fiji	*482.2*	*	Not stated	Vacation	Tropical
Gonçalves, P., Gaspar, A.R., Silva, M.G. da	2012	Qualitative	1	Portugal	446.0		4 star	City	Temperate
Xuchao W., Priyadarsini R., Siew Eang L.	2010	Quantitative	29	Singapore	427.0		3, 4, 5	City	Tropical
Priyadarsini, R., Xuchao, W., Eang, L.S.	2009	Quantitative	29	Singapore	427.0		3, 4, 5	City	Tropical
Pieri, S.P., Ioannis, T., Santamouris, M.	2015	Quantitative	35	Greece	420.0		2, 3, 4, 5	City	Temperate
Onut, S; Soner, S	2006	Quantitative	32	Turkey	*407.2*	*	5 star	City	Temperate
Hui, S., Wong, M.	2010	Qualitative	1	Hong Kong	402.0		Not stated	City	Tropical
Lam, J.C., Chan, A.L.S.	1994	Quantitative	17	Hong Kong	366.0		Not stated	Not stated	Tropical
Lai J.H.K.	2016	Mixed	30	Hong Kong	356.6		4, 5	City	Tropical
Ricaurte, E.	2011	Quantitative	20	Global	351.5		1, 2, 3, 4, 5	City and Vacation	Continental
Chan, W.W., Lam, J.C.,	2002	Quantitative	17	Hong Kong	342.0		3, 4, 5	City	Tropical
AlFaris F., Abu-Hijleh B., Abdul-Ameer A.	2016	Quantitative	12	Dubai	320.5		4, 5	City	Tropical
Bohdanowicz, P., Martinac, I.	2007	Quantitative	184	Europe	297.0		3, 4	City and Vacation	Continental
Huang, K.-T., Wang, J.C., Wang, Y.-C.	2015	Mixed	58	Taiwan	277.0		4, 5	City and Vacation	Temperate
Babatunde O.M., Oluseyi P.O., Denwigwe I.H., Akin-Adeniyi T.J.	2019	Quantitative	28	Nigeria	273.7		1, 2, 3, 4, 5	City and Vacation	Tropical
Santamouris, M., Balaras, C.A., Dascalaki, E., Argiriou, A., Gaglia, A.	1997	Quantitative	158	Greece	273.0		1, 2, 3, 4, 5	City	Temperate
Oluseyi, PO; Babatunde, OM; Babatunde, OA	2016	Quantitative	28	Nigeria	266.0		2, 3, 4, 5	City	Tropical
Yao, Z., Zhuang, Z., Gu, W.	2015	Mixed	45	China	*243.4*	*	3, 4, 5	City	Dry
Cunha, F.O., Oliveira, A.C.	2020	Qualitative	1	Portugal	214.0		4 star	Vacation	Temperate
Filimonau, V., Dickinson, J., Robbins, D., Huijbregts, M.A.J.	2011	Quantitative	2	United Kingdom	213.0		Not stated	Not stated	Temperate
Wang, J.C.	2012	Quantitative	200	Taiwan	*208.0*	*	1, 2, 3, 4, 5	City and Vacation	Temperate
Chedwal, R., Mathur, J., Agarwal, G.D., Dhaka, S.	2015	Quantitative	79	India	207.9		Not stated	City	Tropical
Bianco, V., Righi, D., Scarpa, F., Tagliafico, L.A.	2017	Quantitative	not stated	Italy	203.0		1, 2, 3, 4, 5	Not stated	Temperate
Coles, T., Dinan, C., Warren, N.	2016	Quantitative	29	UK	*190.8*	*	3, 4	City and Vacation	Tropical
Qi, M., Shi, Y., Li, X.,	2017	Quantitative	46	China	187.0		5 star	City and Vacation	Continental
Farrou, I., Kolokotroni, M., Santamouris, M.	2012	Quantitative	90	Greece	182.0		Not stated	City and Vacation	Temperate
Khemiri, A; Hassairi, M	2005	Qualitative	1	Tunisia	170.9		3 star	City	Dry
Becken, S., Frampton, C., Simmons, D.	2001	Quantitative	30	New Zealand	158.6		Not stated	City and Vacation	Dry
Atmaca, M., Yýlmaz, Z.	2019	Quantitative	2	Turkey	*155.5*	*	4 star	City	Temperate
Dat, M.V., Quang, T.N.	2018	Quantitative	32	Vietnam	151.2		3, 4, 5	City	Temperate
Xu C.Q., Pan S., Hui Z., Wu J.S., Wang Y.M., Fan L., Wang X.R.	2014	Qualitative	1	China	*145.7*	*	5 star	City	Dry
Zhao, J., Xin, Y., Tong, D.	2012	Quantitative	19	China	142.5		Not stated	City	Dry
Rosselló-Batle, B., Moià, A., Cladera, A., Martínez, V.	2010	Qualitative	2	Spain	140.0		3, 4	Vacation	Temperate
Udawatta L., Perera A., Witharana S.	2010	Qualitative	1	Sri Lanka	139.9		5 star	Vacation	Temperate
Trung, D.N., Kumar, S.	2005	Quantitative	37	Vietnam	*127.4*	*	3 star	City and Vacation	Temperate
Lu, S., Wei, S., Zhang, K., Kong, X., Wu, W.	2013	Quantitative	27	China	125.3		4, 5	City	Dry
Xin, Y., Lu, S., Zhu, N., Wu, W.	2012	Quantitative	19	China	123.2		4, 5	City	Dry
Tang M., Fu X., Cao H., Shen Y., Deng H., Wu G.	2016	Mixed	24	China	*119.9*	*	1, 2, 3, 4	City	Dry
Lau C., Tang I.L.F., Chan W.	2021	Quantitative	13	China	118.0		4, 5	Vacation	Dry
Teng Z.-R., Wu C.-Y., Xu Z.-Z.	2017	Quantitative	3	China	91.2		2, 3	City	Dry

* numbers are calculated by the author

Table 8: EUI Audit Results
Source: Author's own data

Analysis of the table reveals a discernible trend indicating that higher-quality, more luxurious hotels tend to exhibit greater energy consumption levels (EUI 5 star 297.3 kWh/m^2, EUI 4 star 298.6 kWh/m^2) than hotels offering more basic accommodation (EUI 1 star 238.2 kWh/m^2, EUI 2 star 245.1 kWh/m^2). This result is contrary to the findings of Shiming and Burnett (2002) stating that the class of hotel has no influence on energy consumption. However, it has to be acknowledged that within the above analysis, several other factors (climate, geographical location, quality level of sample hotels) may influence and interfere results. In a more detailed climate analysis shown in Table 9 it is found that properties located in hot and humid areas (Chan et al., 2003; Deng and Burnett, 2002; Prasad and Singh, 2015; Xuchao et al., 2010) consume substantially more energy than those in dry (Khemiri and Hassairi, 2005; Tang et al., 2016; Teng et al., 2012; Xin et al., 2012) and temperate (Atmaca and Yýlmaz, 2019; Dat and Quang, 2018; Santamouris et al., 1996) regions. However, it has to be acknowledged that even within the same region indicators vary significantly. For example, Santamouris et al. (1996) analyzed 158 hotels in the Athens area and concluded an EUI of 273 kWh/m^2 and Pieri et al. (2015) found an EUI of 430 kWh/m^2 when analyzing 32 hotels in Greece. By analyzing Table 9 it is found that, on average, the EUI varies between 149.7 kWh/m^2 in dry regions (179 sample hotels, average sample size 20 hotels) up to 367.7 kWh/m^2 in tropical regions (395 sample hotels, average sample size 23 hotels).

Climate Zone	Number of studies	Average Sample Size	Total Sample Hotels	in %	Mean EUI
Temperate	17	39	668	44.8	245.2
Tropical	17	23	395	26.5	367.7
Dry	9	20	179	12.0	149.7
Continental	3	83	250	16.8	278.5

Table 9: EUI Audit Results split by Climate Region
Source: Author's own data

2.4.5.2. Water Audit Analysis

Table 10 displays the audit findings categorized by water withdrawal in liters per guest night. The variability in consumption per guest night is notable within the data. This is mainly due to the characteristics of climate and operational concepts. Contrary to energy consumption, there is no clear tendency towards climate dependency, as even within the same climate and geographical area, results vary significantly. For instance, Gössling (2015) audited three high-class countryside hotels and found a WUPGN of 317 liters, whereas (Klontza et al., 2016) analyzed eight hotels in the 3-star sector and concluded that WUPGN was 495 liters. Nevertheless, audits conducted in temperate climates (371 hotels, WUPGN 336 liters) generally revealed a lower water consumption compared to those in tropical (64 hotels, WUPGN 474 liters) and dry (16 hotels, WUPGN 484 liters) regions. Due to the limited studies relating to city hotels (4 studies) no implication can be drawn in comparison to countryside hotels (16 studies). Within the data set, hotels in a countryside setting possess a WUPGN of around 400 liters. The mean WUPGN of the whole data set can be concluded to be around 385 liters, which is different to the results of Alhudaithi et al. (2022) which concluded in the literature review part out of 30 studies and WUPGN of 686 liters. The average sample size when analyzing water consumption was 25 hotels with a WUPGN of 383.1 liters.

Source	Year	Research Method	Sample Size	Location of Sample	Liter per guest night	Quality level	City / Vacation Hotel	Climate Region
Charara, N., Cashman, A., Bonnell, R., Gehr, R.	2011	Quantitative	21	Barbados	839.0	Not stated	Vacation	Tropical
Gössling, S.	2001	Quantitative	28	Tansania	685.0	Not stated	Vacation	Temperate
Khemiri, A; Hassairi, M	2005	Qualitative	1	Tunisia	670.7	3 star	City	Dry
Warnken, J., Bradley, M., Guilding, C.	2005	Mixed	16	Australia	630.1	3, 4, 5	Vacation	Dry
Hof, A., Schmitt, T.	2011	Quantitative	not stated	Spain	606.1	Not stated	Vacation	Temperate
Becken, S., McLennan, C.	2017	Quantitative	821	Globally	571.1	1, 2, 3, 4, 5	City and Vacation	Various
Klontza, E.E., Kampragkou, E., Ververidis, K.	2016	Quantitative	8	Greece	495.0	3 star	Vacation	Temperate
Lootvoet, M., Roddier-Quefelec, C.	2009	Quantitative	not stated	Israel, Jordan, Morocco, Tunisisa	466.0	Not stated	Vacation	Dry
Cunha, F.O., Oliveira, A.C.	2020	Qualitative	1	Portugal	458.0	4 star	Vacation	Temperate
Gautam, S., Ahmed, S., Ahmed, K., Haleem, A.	2016	Quantitative	36	India	400.0	5 star	City	Tropical
Debnath S.	2015	Qualitative	2	India	387.7	3, 4, 5	City	Tropical
Ruiz-Rosa I., Antonova N., Mendoza-Jimenez J.	2022	Mixed	70	Spain	366.8	1, 2, 3, 4, 5	Vacation	Temperate
Ratjen, G.	2016	not stated	not stated	Germany	356.8	2, 3, 4, 5	Not stated	Dry
Gössling, S.	2015	Qualitative	3	Greece	317.0	4, 5	Vacation	Temperate
Puig, R., Kiliç, E., Navarro, A., Albertí	2017	Quantitative	14	Spain	315.5	2, 3, 4, 5	Vacation	Temperate
Díaz Pérez, F.J., Chinarro, D., Guardiola Mouhaffel, A.	2019	Quantitative	12	Spain	295.6	1, 2, 3, 4, 5	Vacation	Temperate
Rico-Amoros, A.M., Olcina-Cantos, J., Sauri, D.	2009	not stated	not stated	Spain	287.6	1, 2, 3, 4	Vacation	Temperate
Bohdanowicz, P., Martinac, I.	2007	Quantitative	184	Europe	278.5	3, 4	City and Vacation	Various
Meade B., Pringle J.	2001	Quantitative	5	Jamaica	268.8	Not stated	Vacation	Tropical
Barberan, R; Egea, P; Gracia-de-Renteria, P; Salvador, M	2013	Mixed	1	Spain	252.0	4 star	City	Temperate
Gabarda-Mallorquí, A., Garcia, X., Ribas, A.	2017	Qualitative	35	Spain	251.0	1, 2, 3, 4, 5	Vacation	Temperate
Deyà Tortella, B., Tirado, D.	2011	Quantitative	196	Spain	156.6	1, 2, 3, 4, 5	Vacation	Temperate
Styles D., Schoenberger H., Galvez-Martos J.L.	2015	Quantitative	2	not stated	140.0	3 star	Not stated	Temperate
Cobacho, R., Arregui, F., Parra, J.C., Cabrera, E.,	2005	Qualitative	1	Spain	83.0	4 star	Not stated	Temperate

Table 10: WUPGN Audit Results
Source: Author's own data

2.4.5.3. Waste Audit Analysis

Several authors emphasized the missing data and documentation regarding waste handling in hotels (Chan, 2009; Warnken et al., 2005). Previous research has, however, rarely quantified the relative carbon share of waste management in hotels due to data quality and (un)availability (Bhochhibhoya et al. 2020). As a result of this study, there is too little data to display any meaningful comparison of performed waste audits and compare results to geographical and operational characteristics. Nevertheless, several studies conducted waste management studies and predominantly compared kg per person (WkgP) and per guest night (WkgGN), which are treated as the same indicator for this research. The largest study in this research field was conducted by Pham Phu et al. (2018) analyzing solid waste of 120 hotels in Vietnam. An average of 2.28 kg per guest per day was found, of which two-third is biodegradable. A strong correlation between waste generation and quality level, size of hotel, price level, garden and number of restaurants was revealed. Debnath (2015) conducted a waste management audit of two city hotels in India and concluded a WkgGN of 1.38 kg. A similar result (1.5 kg WkgGN) was achieved by Rosselló-Batle et al. (2010) and Papargyropoulou et al. (2016) when investigating two countryside hotels in Spain and one 5-star city hotel in Malaysia respectively. Similarly, Ball and Taleb (2011) concluded a WkgGN of 1.5 kg within the Egyptian hotel industry investigating 24 5-star hotels. The authors executed several linear regressions and revealing that weight of waste significantly correlates with number of rooms and average occupancy percentage. With a WkgGN of 1.9 kg slightly different results illustrated Puig et al. (2017) within the study investigating 14 hotels countryside hotels in Spain from 2- to 5-stars. In the study of Camilleri-Fenech et al. (2020) and Papargyropoulou et al. (2016) a 5-star hotel was investigated as a single case study and the weight of waste was differentiated by outlet and service time. In the latter results revealed a WkgP of 1.2 kg in breakfast service, 1.1 kg in lunch service and 1 kg in dinner service. This result is quite to the contrary of Camilleri-Fenech et al. (2020) concluding a WkgP of 0.1 kg in breakfast, 0.21 kg in lunch, 0.16 kg dinner and 0.48 kg buffet. Room waste accounted for a WkgP of 0.27 kg, resulting in a total waste weight of 0.74 kg or 1.06 kg depending on whether a-la-carte dinner or buffet respectively is consumed. Both results demonstrate that food waste generation is intrinsically linked to how food is provisioned and consumed (Papargyropoulou et al. 2016). Nevertheless, waste indicators are growing in prominence (Campos et al., 2024), audit results cannot be summarized as there is no uniform waste collection technique.

2.4.5.4. GHG Emissions Audit Analysis

Similarly to waste consumption, studies relating to GHG emissions are still evolving, which limits meaningful analysis and comparisons. The range of COGN displayed in previous studies varies significantly between 9.2 kgCO_2e and 101 kgCO_2e per guest night (average 33.3 kgCO_2e per guest night), depending on various factors (see Table 11).

Source	Year	Sample Size	Location	Calculation Tool	Scope of Calculation	COGN	Quality level	City / Vacation Hotel	Climate Region
Debnath S.	2015	2	India	not stated	not stated	101.0	3, 4, 5	City	Tropical
Hu, A.H., Huang, C.-Y., Chen, C.-F., Kuo, C.-H., Hsu, C.-W.	2015	1	Taiwan	PAS 2050:2011	Scope 1, Scope 2, few items from Scope 3	89.2	5 star	City	Temperate
Díaz Pérez, F.J., Chinarro, D., Guardiola Mouhaffel, A.	2019	12	Spain	Greenhouse Gas Protocol	Scope 1, Scope 2	29.0	1, 2, 3, 4, 5	Vacation	Temperate
Ratjen, G.	2016	not stated	Germany	not stated	not stated	27.6	2, 3, 4, 5	Not stated	Dry
Tsai, K.-T., Lin, T.-P., Hwang, R.-L., Huang, Y.-J.,	2014	41	Taiwan	Intergovernmental Panel on Climate Change (IPCC)	Scope 1, Scope 2	18.4	3, 4, 5	City	Temperate
Huang, K.-T., Wang, J.C., Wang, Y.-C.	2015	58	Taiwan	Hotel Carbon Managemenet Intitiative	Scope 1, Scope 2	14.6	4, 5	City and Vacation	Temperate
Filimonau V., Rosa M.S., Franca L.S., Creus A.C., Ribeiro G.M., Molnarova J.	2021	7	Brazil, Peru	ISO 14040:2006/ 14044:2006 standards	Scope 1, Scope 2	13.5	1, 2, 3, 4, 5	City	Tropical
Filimonau, V., Dickinson, J., Robbins, D., Huijbregts, M.A.J.	2011	2	United Kingdom	Intergovernmental Panel on Climate Change (IPCC)	Scope 1, Scope 2	10.0	Not stated	Not stated	Temperate
Beccali, M., La Gennusa, M., Lo Coco, L., Rizzo, G.	2009	4	Italy	Kyoto Protocoll	only electrizity use	9.2	1, 2, 3, 4, 5	City and Vacation	Temperate

Table 11: COGN Audit Results
Source: Author's own data

In the study of Tsai et al. (2014) the GHG emissions caused by a guest staying one night at a hotel was assessed by determining what kind of resource consumptions are shared by each guest. Although guest rooms, public spaces, and administration spaces were included, restaurants, kitchens, and conference rooms were excluded as not all guests are using them. Results of a sample of 41 hotels indicate that while averaging a COGN of 18.4 $kgCO_2e$, luxury hotels generally consume COGN 29 $kgCO_2e$ compared to budget hotels which consume substantially less (COGN 12.5 $kgCO_2e$). A similar result regarding the increasing COGN when it comes to the quality level of hotel was presented by Filimonau et al. (2021) (average COGN 13.6 $kgCO_2e$, 13.5 $kgCO_2e$ for budget hotels, 23.7 $kgCO_2e$ for luxury hotels). Furthermore, Huang et al. (2015) found with a COGN of 14.6 $kgCO_2e$ a similar result for 58 upper-class hotels in Taiwan. While Díaz Pérez et al. (2019) found a similar result for 14 hotels located in Spain with a COGN of 14.2 $kgCO_2e$, the weighted average of luxury hotels (COGN 40.3 $kgCO_2e$) was considerably higher than other previous studies. An early study of Beccali et al. (2009) covering four hotels of all quality levels calculated a COGN of 9.2 $kgCO_2e$ by converting only electricity use with a conversion table of the Kyoto Protocol.

Interestingly, certain studies noted that their findings exhibited an unusually high disparity and lacked precedence in prior research. For example, Hu et al. (2015) analyzed one 5-star hotel in Taiwan and found a comparable value on COUI with the study of (Xuchao et al., 2010) but a COGN of 89.2 $kgCO_2e$. A similar result was reported by a study investigating two upper-class hotels in India (COGN 101 $kgCO_2e$) (Debnath, 2015). This indicates that calculation habits are still vague and comparability is limited due to operational characteristics and different calculation schemes. As listed in Table 11 there is no coherent calculation tool and scope of calculation. Models used for calculation are the Greenhouse Gas Protocol (Ranganathan, 2004), PAS 2050:2011, ISO 14040:2006, ISO 14044:2006, Hotel Carbon Management Initiative (HCMI), or Intergovernmental Panel on Climate Change (IPCC). Whereas most studies conducted a study based on Scope 1 and Scope 2, some integrated some parts of Scope 3 emissions (Hu et al., 2015). The average sample size is with 14 hotels comparatively to other environmental research fields rather small.

2.5. Discussion and Conclusion Literature Review

Employing reproducible research criteria, an extensive keyword search across pertinent research databases is conducted, screening through 1,600 articles, ultimately identifying 117 for in-depth analysis. What becomes apparent in the synopsis of the relevant literature presented is that the research field has matured significantly and has steadily gained relevance in recent years. Especially studies relating to energy and water consumption are largely dominating this research field. However, more and more studies are related to waste consumption tracking. GHG monitoring is in its early stages, primarily focusing on Scope 1 and 2 emissions, with only occasional attention paid to aspects of Scope 3. Nevertheless, methodologies of waste and GHG resource benchmarking are still blurred and rarely performed consistently. Quantitative surveys and questionnaires emerged as the primary data collection methods among scholars, occasionally supplemented by existing databases for analysis (Becken and McLennan, 2017; Bohdanowicz and Martinac, 2007). While descriptive statistics were widely used, many studies went further by applying correlation and regression analyses to predict resource consumption, identify usage patterns, and determine key influencing factors. The geographical distribution of the sampled studies highlights a strong research focus in Asian and Southern European countries, with a notable absence of studies from Central Europe with continental climates, presenting a gap for future research.

A critical synthesis of the literature underscores the necessity for resource intensity metrics to encompass both resource input and relevant reference units to ensure benchmarking comparability. While Energy Use Intensity (EUI) based on a per-floor basis prevailed as a primary intensity variable, suggestions were made to integrate occupant-related metrics, especially pertinent amid events like the Coronavirus pandemic, which could skew EUI figures. This led to the identification of additional intensity metrics such as Energy Use Per Guest per Night (EUPGN), Energy Use Per Occupied Room (EUPOR), Energy Use Per Room (EUPAR), and Energy Use Per Bed (EUPAB). With regard to water-related intensity metrics, an even more user-focused intensity metric is needed, water withdrawal per guest night (WUGN) is found to be dominant. Similar results are revealed in waste-related metrics, measuring kg solid waste per person (WkgP) or per guest night (WkGN). Measuring GHG consumption is found to be highly varying, but a user-centric approach is evident as well (kgCO_2e per guest night, COPGN). Nevertheless, results advocate for a range of intensity metrics over a singular benchmark value to better capture energy consumption dynamics. As a result of the findings, the extracted metrics used in EGWW consumption for the hotel industry, including reference units, units of measurement, and time frames, are presented in Table 12. The table displays the five most frequently used intensity metrics, along with their frequency counts, both in terms of total occurrences and their usage within studies that conducted resource audits. Resulting abbreviations are formed out of the respective frequency counts.

	Resource Input	Reference Unit	Unit of measu-rement	Outlets analysed	Time unit	Top 5 metrics	Abbre-viation	Frequency Count Total*	Frequency Count Audits**
Energy	electricity, chilled water, hot water, steam, diesel oil, gasoline and natural gas, renewable energy	per floor area, per room, per outlet, per guest night, per bed, per employee, per food cover	MWh, kWh, MJ	per building, per outlet	per day, per month, per year	*Energy use intensity*	EUI	68	46
						Energy use per guest night	EUPGN	19	15
						Energy use per occupied room	EUPOR	10	5
						Energy use per room per year	EUPAR	9	6
						Energy use per bed per year	EUPAB	4	1
Water	water withdrawal, grey water, recycled water, embodied water use	per floor area, per guest night, per room, per food cover, per person	liter, m3, kgCo2/e, kg	per building	per day, per month, per year	*Water use per guest night*	WUGN	31	26
						Water use per floor area per year	WUI	9	8
						Water use per occupied room	WUOR	5	3
						Water use per floor area per day	WUId	7	2
						kg laundry per guest night	LGN	3	1
Waste	solid waste, food waste	per floor area, per guest night, per person, per food cover	kg, liter	per building	per day	*kg per person per day*	WkgPG	6	4
						kg per guest per guest night	WkgPGN	4	3
						liter per person per day	WlPG	3	2
						kg per floor area	WkgI	2	2
						liter per floor area	WlPG	1	1
	Standards for measuring GHG emissions	**Reference Unit**	**Unit of measu-rement**	**Outlets analysed**	**Time unit**	**Top 5 metrics**	**Abbre-viation**	**Frequency Count Total***	**Frequency Count Audits****
GHG	Greenhouse Gas Protocol, PAS 2050, International Organization for Standardization (ISO)/TS 14067, Life Cycle Assessment Approach (LCA), Hotel Carbon Management Initiative (HCMI), or Intergovernmental Panel on Climate Change (IPCC)	per floor area, per guest night, per occupied room, per room, per food cover	kgCO2e (Scope 1, Scope 2, Scope 3)	per building	per day, per year	*kgCO2e per guest night*	COPGN	18	12
						kgCO2e per floor area per year	COUI	9	6
						kgCO2e per guest room per year	COPAR	5	4
						kgCO2e per bed	COPAB	1	1
						kgCO2e per occupied room	COPOR	3	3

* the frequency count is defined as whether an indicator was mentioned in the respective article
** out of frequency count total, counted when article was applying the indicator(s) to the research sample for further inferential analysis

Table 12: Intensity Indicators Overview
Source: Author's own data

The review of EUI audit results (2,280 hotels) revealed an average of 273.9 kWh/m^2, with variations attributed to climate, hotel quality, and service level. Notably, studies in humid regions exhibited higher energy consumption. However, considerable variations were found as well, regardless of the above-written factors. For example, in the study of Shiming and Burnett (2002) conducting research in hotels in Hong Kong, an EUI of 563.8 kWh/m^2 was concluded. In the study of Zhao et al. (2012) hotels in mainland China were analyzed, and a comparatively lower EUI of 142.5 kWh/m^2 was discovered. This result indicates that numbers may not be reliable and that a unified benchmarking tool is necessary. Water-related metrics assess water withdrawal, revealing an average WUPGN of 383.1 liters. Notably, none of the audits reported findings related to water discharge or the use of recycled water, indicating a significant gap in the literature. Waste-related audit results are limited and lack consistency, with relatively few studies addressing this area. The most comprehensive study to date analyzed 120 hotels and reported an average waste generation of 2.28 kg per guest per day (Pham Phu et al., 2018). Audit results related to waste management and GHG emissions remain scarce and inconsistent, highlighting a clear research gap in these critical areas. To enable meaningful comparisons and improve data reliability, future research should not only expand coverage but also clearly define system boundaries and adopt standardized methodologies.

Scholars concur on the importance of displaying specific hotel parameters to facilitate result clustering and enhance comparability. Operational and physical attributes, alongside location and climate factors, were identified as crucial parameters impacting energy consumption. Additionally, the study observed an increase in energy consumption with quality level but found no significant difference between 4-star and 5-star hotels. However, it has to be acknowledged that studies analyzing solely 5-star properties are rare (Lanka Udawatta et al., 2010; Önüt and Soner, 2006; Xu et al., 2014). The studies primarily analyze a data set with different quality levels, making it harder to interpret results. While the literature generally suggests that countryside hotels tend to consume more energy, often due to features like wellness areas that are typically more resource-intensive, the analysis performed in this SLR found the opposite: countryside hotels sometimes exhibit lower overall energy consumption compared to their urban counterparts. This contradiction highlights the complexity of influencing factors such as operational practices, building design, and guest behavior, which may offset expected energy demands. Analyzing dependent factors on waste consumption is not well-researched due to the complexity of waste measurement. However, a notable correlation between waste production and various factors such as hotel size, quality standards, pricing, presence of gardens, and the number of restaurants seems evident.

With regard to benchmarking, internal and external procedures are commonly performed by hotels. While internal benchmarking is common to track the progress in time series, external benchmarking is considered more complex. It has been highlighted that only hotels with the same characteristics and location are eligible for comparison. Thus, clustering must take place to create valid benchmarks. The predominant factors influencing resource consumption, as derived from the literature, can be categorized as follows:

- Operational factors: average occupancy rate, average overnights, hotel operation concept, hotel classification, types of services offered, seasonality, operational hours, chain affiliation, resource-saving measures, outsourcing
- Physical factors: building structure, total number of rooms and beds, number of floors, gross floor area (GFA), design, resource extensive outlets such as wellness, swimming pool, laundry, HVAC system type
- Age factors: age of the facility, years of usage, operation and maintenance schemes
- Location and Climate: climatic region, location

Without the creation of a valid peer group, benchmarking resource consumption with the proposed intensity indicators is deemed ineffective and may result in erroneous management decisions regarding resource-saving initiatives. In conclusion, the literature review indicates, consistent with other authors (Campos et al., 2024; Guix, 2020; Guix et al., 2018; Kang et al., 2015), that research aiming to integrate environmental concerns into hotel operations is still in an exploratory phase. It becomes apparent that further exploration of influencing factors on resource consumption, large-scale implementation of intensity metrics, integration of regulatory framework developments, and application of the results to a data set to non-researched geographical area, such as Germany and Austria, is advisable. A more detailed discussion of the identified research gaps is presented in Section 4.1

3. Existing Environmental Initiatives

Given the novelty of the research topic, it is essential to supplement the existing scientific literature with insights from industry publications. This chapter provides a comprehensive overview of industry-related ESG reporting, alongside the legislative frameworks that underpin it. Additionally, it examines the various certifications and reporting frameworks utilized within the hotel and real estate operations sector, focusing on key intensity metrics and audit outcomes. These standards, often established by governmental bodies or regulatory agencies, set forth guidelines and requirements for companies to disclose their ESG performance. In addition, the chapter also presents an analysis of ESG reports from the world's largest hotel companies, critically evaluating their reporting structures and associated certification schemes. However, it is important to note that over 50 schemes exist (ETGG, 2022; UNWTO, 2023), specifically designed for the tourism and hotel industry to assess ESG performance, and not all can be encompassed within the scope of this analysis. Therefore, a targeted keyword search focusing on intensity metrics and their relevant synonyms was conducted to determine whether the analyzed frameworks explicitly incorporate such metrics within their structure. The most relevant standards and fundamentals related to the research aim are reviewed below.

3.1. European Union Regulatory Framework

The European Union regulatory framework for sustainability encompasses a range of policies, regulations, and directives designed to promote environmental, social, and economic sustainability across the European Union. The framework is part of the European Union's broader efforts to transition to a greener, more sustainable economy, aligning with goals of the Green Deal like achieving carbon neutrality by 2050 and promoting sustainable finance (Eckert and Kovalevska, 2021). With regard to reporting on sustainability matters, several directives outlined below form the foundational framework.

3.1.1. Corporate Sustainability Reporting Directive (CSRD)

The CSRD is regulated by the Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022. The directive establishes and governs ESG reporting requirements for management reporting and supersedes the Non-Financial Reporting Directive (NFRD) from the financial year 2024 onwards. It extends the scope for mandatory non-financial reporting and implements a mandatory report audit with limited assurance for large[6] and listed companies in EU-regulated markets (McCalla-Leacy et al., 2022). The first reporting for large publicly listed companies is in 2025, using 2024 data. The main requirement is the double materiality concept, where financial materiality describes the outside-in perspective, and impact materiality provides the inside-out perspective by evaluating the company's impact on people and the environment (Hummel and Jobst, 2024). This cycle underscores the mutual dependency between businesses and their local environments and emphasizes the importance of sustainable resource management to ensure long-term resilience for both the hotel and the community. As an example, the impact of high water usage and double materiality is displayed in Figure 8. To comply with the CSRD, companies are required to follow the specific reporting standards outlined in the ESRS.

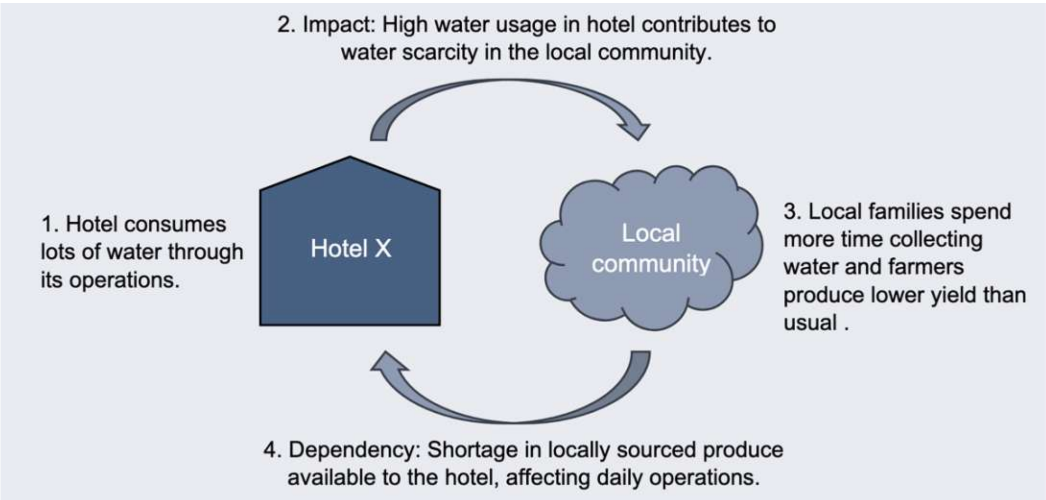


Figure 8: Double Materiality Example High Water Usage in Hotels
Source: Sustainable Hospitality Alliance (2023, p. 4)

3.1.2. European Sustainability Reporting Standards (ESRS)

As part of CSRD the European Financial Reporting Advisory Group (EFRAG) is tasked with creating its own European standards for sustainability reporting. These standards are designed to ensure that the information disclosed in sustainability reports is clear, relevant, comparable, and verifiable by establishing defined content requirements and standardized reporting metrics. Therefore, the ESRS is claimed as a set of reporting standards used to meet the requirements of the CSRD (KPMG, 2023). The ESRS generally comprises three categories: (1) cross-cutting standards, (2) topical standards, and (3) sector-specific standards. By means of a delegated act[7], the European Commission

[6] Meeting two out of three following criteria: (1) Net Turnover exceeding 40 million EUR, (2) net assets exceeding 20 million EUR, (3) greater than an average of 250 employees

[7] Commission Delegated Regulation (EU) 2023/2772 of 31 July 2023 supplementing Directive 2013/34/EU of the European Parliament and of the Council as regards sustainability reporting standards

adopted a first set of standards by July 2023, consisting of cross-cutting standards (ESRS 1 and 2) and topical standards (ESRS E1 to E5, ESRS S1 to S4, ESRS G1). For the context of this research, the first set of standards is analyzed with a keyword search for intensity metrics relating to EGWW resource benchmarking (see Table 13).

Topic	Input Factor	Reference Unit	Unit	Intensity metric	Source Delegated Regulation (EU) 2023/2772
Energy	Energy consumption and mix, split in total energy consumption from fossil fuel, nuclear sources, renewable sources	per million net revenue in Euro	MWh	Energy intensity based on net revenue (high climate impact sectors)	Disclosure Requirement E1–5 Paragraphs 35-43, AR36-38
Water	Total water consumption, total water recycled (reused), total water stored	per million net revenue in Euro, additional intensity ratios based on other denominators possible	m^3	Water intensity based on net revenue	Disclosure Requirement E3–4 Paragraphs 26-29, AR31
Waste	Total amount of waste from operations, breakdown in hazardous and non-hazardous, waste types incineration, landfill, other disposal, total amount and percentage of non-recycled waste, total amount of radioactive waste		Tonnes or kg		Disclosure Requirement E5–5 Paragraphs 37-40
GHG	Gross Scope 1, Scope 2, Scope 3 emissions, total GHG emissions	per million net revenue in Euro	Tonnes CO2e	GHG emissions intensity per net revenue	Disclosure Requirement E1–6 Paragraphs 44-55, AR23, AR 39-47

Table 13: ESRS Intensity Metrics
Source: Author's own illustration, data sourced from Commission Delegated Regulation (EU) 2023/2772

While specific input factors are disclosed, reference units primarily focus on a per revenue basis (Resource intensity per million Euro revenue). Consequently, while different economic sectors can be compared, operational efficiency remains unmonitored. Moreover, within water-related metrics, additional intensity ratios based on alternative denominators are conceivable (E3-4 AR 31). Furthermore, the directive refers to the yet non-existent sector-specific standards for relevant additional intensity ratios. Nevertheless, this framework can also serve as a foundational reference for developing or refining intensity metrics, especially in sectors like the hotel industry, where sector-specific ESRS have not yet been established.

3.2. Sustainable Development Goals (SDGs)

At the UN headquarters in New York, the Open Working Group, convened by the UN General Assembly, put forth a comprehensive proposal for global Sustainable Development Goals (SDGs), consisting of 17 goals and 169 targets (United Nations, 2023) (see Figure 9). The SDGs are preliminary designed as a framework for countries and governments, but also provide a roadmap that involves stakeholders on subnational levels (i.e., companies). Although not legally binding, UN member states are expected to implement the SDGs into their national policies. Several authors have criticized that the SDGs related to the hotel industry, such as SDG 6, “water and sanitation,” do not consider all necessary elements (Vanham et al., 2018) and have little academic reflection in parameter choice (Brussel et al., 2019). The recent Development Goals Report further underlines this, indicating a lack in data quality and highlighting the existent data gaps to create and measure valid indicators (United Nations, 2021).

Figure 9: 17 SDGs Overview
Source: Statistik Austria (2024, p. 1)

Additionally, in March 2015, a preliminary set of 330 appropriate indicators to assess sustainability were introduced. As of 2023, 231 official indicators are in use and annually reviewed by several expert groups (United Nations, 2024). Nevertheless, several authors highlighted that the proposed indicators are not relevant for all scales, resulting in practitioners ‘cherry-picking’ indicators to measure success, often selecting SDGs that favor their business (Heras-Saizarbitoria et al., 2022; Lu et al., 2021). Within the indicator set in use, when conducting a keyword search, the following intensity metrics could be identified as relevant for this research (United Nations, 2024):

- Energy: Renewable energy share in total energy consumption (*Indicator 7.2.1.*)
- Waste: Hazardous waste generated per capita (*Indicator 12.4.2. (a)*)

In conclusion, despite extensive theoretical groundwork on indicator quality standards, practical users often lack assurance regarding the adequacy of these indicators in measuring the phenomena under observation (Hák et al., 2016; Kim, 2023). Furthermore, indicators are not directly tailored for companies, asking for a framework to measure progress on a corporate level (Gebara et al., 2024).

3.3. Environmental Reporting Standards

When it comes to reporting environmental performance, several well-known, internationally recognized standards play a crucial role in promoting transparency and accountability in corporate sustainability practices worldwide. These standards provide a structured framework for organizations to measure, manage, and report their environmental impacts. This section outlines these key reporting standards, emphasizing their importance in driving consistent and transparent sustainability practices across industries.

3.3.1. International Standards Organization (ISO)

Reporting schemes to assess a company's environmental performance build on existing norms issued by the International Standards Organization (ISO). However, it is often criticized that these are general formulations and so lack specificity to an industry sector, such as tourism and hotels (Hsiao et al., 2014). The ISO 14000 series provides guidelines for the development of an Environmental Management System (EMS) and supporting audit program in the fields of waste management, energy use, and pollution prevention. The ISO 14001 standard specifies the requirements for an EMS and is continuously recognized by scientific researchers as relevant in the hotel industry (Jackson, 2010; Rodríguez-Antón et al., 2012; Legrand et al., 2014; Camillo, 2015). Furthermore, the ISO 14001 is the basis for the EMAS audit scheme (see Chapter 3.2.1). The framework is based on the (1) plan, (2) do, (3) check, and (4) act (PDCA) principle. While ISO 14001 can support companies in improving environmental performance, it does not specify any criteria or indicators that must be fulfilled to obtain certification (Sloan et al., 2016). A company can be certified by an external certification authority against the ISO 14001 standard. Regarding the hotel sector, Chan (2011) investigated SME hotels and found that more than 60% of surveyed properties had minimal understanding of an EMS based on ISO 14001. When implementing an EMS the ISO 9001:2015 is an international standard for quality management systems (QMS) (ISO, 2015). As a consequence, procedures, and standards derived from an ISO 9001 certification support identifying resource consumption sources and implementing management practices (Wilson and Campbell, 2016). Furthermore, the guidelines are a repository of the learned knowledge and inform decision-makers about environmental issues (Filimonau et al., 2011). The study of Rodríguez-Antón et al. (2012) found that ISO 9001 and ISO 14001 are most commonly adopted in the hotel industry when implementing an EMS. However, upon screening both norms using a keyword search relevant to this study, it was discovered that they do not include any intensity indicators related to EGWW.

A further ISO norm modeled after the ISO 14001 and ISO 9001 is the ISO 50001 to improve energy-related performance and identify energy reduction to build an EMS consequently (ISO, 2018). Part of the standard is the importance of measuring and monitoring data to track performance and identify deviations. Metrics included are energy consumption per reference unit or energy savings achieved compared to a baseline year. Furthermore, ISO 50001:2018 emphasizes the differentiation of the various types of energy (ISO, 2018). In a hotel setting, an EMS based on ISO 50001 was tested in the study of Cabello Eras et al. (2016) using a baseline year to evaluate the effectiveness and considering operational and physical parameters in two Cuban hotels, highlighting that current indicators do not fulfill anticipated needs. For estimating, verifying, and reporting a company's environmental information, the ISO 14064:2018 series is eligible. Being the standard for the Greenhouse Gas Protocol Corporate Accounting and Reporting Standards, Part 1 (ISO 14064-1:2018) specifies principles and requirements (e.g., in design, development, management, reporting, and verification) for reporting GHG emissions (ISO, 2020). In conclusion, as noted by other researchers (Rosselló-Batle et al., 2010; Teng et al., 2012; Warnken et al., 2005; Jones et al., 2014), the above-described standards could mean that hospitality organizations may require extensive use of different standards to build and operate an effective EMS.

In conclusion, ISO standards provide a foundational framework for certifications, environmental labels, and audit schemes, promoting consistency and compliance across sectors. However, these norms primarily offer procedural guidance and regulatory alignment rather than detailed quantitative tools. Specifically, they do not typically include intensity metrics which are essential for operational benchmarking and performance evaluation.

3.3.2. Global Reporting Initiative (GRI)

Being a non-governmental organization based in the Netherlands, GRI was founded in 1997 and consists of environmental reporting standards for organizations of any size, public or private, anywhere in the world (Hummel and Jobst, 2024). GRI incorporates elements from ISO 14001, ISO 14064, and ISO 50001 to ensure consistency in sustainability reporting (Del Mar Alonso-Almeida et al., 2014). By adhering to GRI guidelines, organizations can ensure their reports are transparent, consistent, and comparable, contributing to greater accountability and fostering sustainable development globally. According to the 2022 KPMG Survey of Sustainability Reporting, 96% of all G250[8] companies report on ESG matters, whereas GRI is 78% of the dominant reporting scheme (McCalla-Leacy et al., 2022). GRI standards are split into three series: Universal Standards, Sector Standards, and Topic Standards. While no sector-specific standards exist for real estate or hotel operations, the topic standards GRI 302: Energy, GRI 303: Water and Effluents, GRI 305: Emissions, and GRI 306 Waste are relevant for this research (GRI, 2023). Regarding energy and GHG intensity ratios, GRI emphasizes reporting organization-specific metrics such as units of product (e.g., available rooms in a hotel case, EUPAR, COPAR), size (e.g., floor space, EUI, COUI), number of full-time employees or monetary units (GRI, 2022). Within water and waste-related figures, no intensity metrics could be revealed. While some of the largest hotel companies in the world generally use GRI (see Table 15), several studies indicate that usage within the SME hotel segment is still improvable (Halmi, 2020; Yang et al., 2021). An example of the 2021 GRI reporting is available by Hyatt and IHG, showing that the information is still highly descriptive (Hyatt, 2021a; Intercontinental Hotels, 2022a).

3.3.3. Sustainability Accounting Standard Board (SASB)

SASB was founded in 2011 and is, similar to GRI, used to communicate sustainability information to different stakeholders of an organization. In 2022, SASB and the International Financial Reporting Standards (IFRS) Foundation were consolidated into the International Sustainability Standards Board (ISSB) to integrate sustainability disclosure standards (SASB, 2022). While around half of the companies within the G250 report with SASB, it is the dominant standard in the US (75% of all G250 companies) and Germany (77% of all G250 companies) (McCalla-Leacy et al., 2022). Being often perceived as more sector-specific than GRI (GRI and SASB, 2021), SASB comprises 77 industries, whereas the “Hotels & Lodging” sector is perceived relevant for this research

[8] G250 refers to the largest 250 companies by revenue based on the Fortune 500 ranking (McCalla-Leacy et al., 2022)

(SASB, 2018). Reporting generally includes disclosure topics, accounting metrics, technical protocols, and activity metrics. Regarding accounting metrics, energy consumed is measured in Gigajoules (Code SV-HL-130a.1), water withdrawn in m^3 (Code SV-HL-140a.1). Within activity metrics, the Hotels & Lodging Standards request for available room-nights, average occupancy rate and total area in square meters. Direct and indirect GHG emissions are not integrated within the industry standard. While SASB audit results are generally displayed in absolute figures (Intercontinental Hotels, 2021; Marriott International, 2021), the Hilton SASB table 2020 displays per square meter in energy (EUI) and water (WUI) calculations (Hilton Worldwide, 2020).

3.3.4. Greenhouse Gas Protocol Corporate Accounting and Reporting Standards

This standard was built onto the Publicly Available Specification (PAS) 2050 standard and was released in 2011. It is designed for companies to inventory and report GHG emissions by categorizing them into Scope 1, Scope 2, and Scope 3 (GHG Protocol, 2023; World Business Council for Sustainable Development, 2005; GHG Procotol, n.D.). Organizational boundaries are set either by equity share (GHG emissions are accounted according to the share of equity) or by control approach (GHG emissions are accounted 100% where the company has control of) (Landry et al., 2023). Although various cross-sector, country-specific, sector-specific as well as for countries and cities calculation tools exist (GHG Protocol, 2023), no industry-specific version or intensity metrics could be revealed. For years, the hotel industry has universally embraced and ratified the Greenhouse Gas Protocol for estimating carbon footprint (Huang et al., 2015). Furthermore, it serves as a basis for the Hotel Carbon Measurement Initiative (Chapter 3.4.1) and Cornell Hotel Sustainability Benchmark Index (Chapter 3.4.5).

3.1. Fundamentals of (Non-)Financial Accounting in the Hotel Industry

In addition to international sustainability reporting frameworks, a brief overview of reporting practices within the hotel industry is presented. Financial reporting and operational management within the hotel industry are typically guided by the Uniform System of Accounts for the Lodging Industry (USALI), a standardized accounting framework first introduced by the Hotel Association of New York in 1926 (Schmidgall and DeFranco, 2015). Based on a cost center system, USALI was designed to classify, organize, and present the financial information of hotels by predominantly supporting operational reporting by providing main revenue KPIs (e.g., rooms available, rooms sold, average daily rate) and the respective cost side. The reporting standard applies to all properties and provides only limited tailoring options to avoid ambiguity and strengthen conformity (Chibili, 2019). Furthermore, uniform accounting encourages benchmarking efforts within similar properties. Currently, the 11th edition is based on US GAAP[9] referencing international standards such as IFRS[10] (AHLEI and HFTP, 2014).

The Global Finance Committee (GFC) comprises executive personnel from the most prominent hotel brands, operators, and educators and is working on a 12th edition. The aim is to incorporate industry feedback and changes in the regulatory framework and energy, water, and waste matters into the accounting standard. Being in charge since 01 January 2024, the new framework is serving as a common benchmarking tool for the lodging industry. The utilities section of the hotel reports split energy consumption into electricity, fuels, gases, and district energy, renewable energy, and vehicle fuels. Municipal water (i.e., water withdrawal), other water, and sewer should be reported within water-related figures. In the waste section, data on landfills, recycled waste, composted waste, and others are necessary for reporting. Contracted/outsourced services need to be accounted for as well, deriving into an overall cost figure of energy, waste, and waste expenses. However, it must be acknowledged that USALI works on a cost basis and is, therefore, highly dependent on area-specific cost metrics. The implementation of consumption-based intensity metrics such as EUI, WUOR, or WkgPGN is planned (HFTP, 2022). Until such metrics are formally integrated, the USALI framework remains constrained in its capacity to facilitate comprehensive and standardized benchmarking of sustainability performance within the lodging industry.

3.2. Environmental Audit Schemes

The following environmental audit schemes provide guidelines and methodologies for conducting comprehensive audits of environmental practices within companies. By adhering to these standards, companies can systematically evaluate their environmental impact, identify areas for improvement, and implement strategies to enhance sustainability. The following section evaluates the most prominent schemes related to the hotel industry.

[9] The Generally Accepted Accounting Principles (GAAP or US GAAP) are a collection of commonly-followed rules for financial reporting adopted by the U.S. securities and Exchange Commission (SEC). US GAAP ensures that reporting is transparent and consistent regardless of a company's size and sector (Ernst & Young, 2021).

[10] Similar to US GAAP, the International Financial Reporting Standards (IFRS) are a set of accounting rules for the financial statement of public companies. IFRS is predominantly used by European companies (Deloitte, 2021).

3.2.1. Eco-Management and Audit Scheme (EMAS)

Article 46 of regulation EC 1221/2009 regarding revision of the Eco-Management and Audit Scheme (EMAS) places the foundation for more rigorous performance-orientated reporting (European Commission, 2009). The EMAS scheme already includes ISO 14001 and requires companies to report indicators related to energy, water, waste, material efficiency, as well as GHG emissions (EMAS, 2010) emphasizing stricter requirements (EMAS, 2011; Legrand et al., 2014). Deriving from an expert consultation of Best Environmental Management Practices in the Tourism Sector (Styles et al., 2013), the Commission Decision 2016/611 Document provides an overview of tourism sector-specific environmental performance indicators (European Commission, 2016). The identified predominant energy efficiency indicator is EUI measured in kWh per m^2 (i43 environmental performance indicator), arguing that measuring by m^2 is less influenced by different levels of service and operational characteristics, enabling a more robust comparison across accommodation establishments. Regarding water consumption, the relevant performance indicator is WUGN (i7 environmental performance indicator) or LGN (i26, i30 environmental performance indicator). In waste management, the WkgPGN has been identified (i37 environmental performance indicator). The minimum level of reporting for hotels is recommended to be per site or aggregated to the organization level. Benchmarks of excellence are provided on a headline basis (e.g., WUGN < 140 liters in full-service hotels, water consumption ≤ 2,0 m^3 per employee per year). The sub-metering of all major resource-consuming processes, as well as the implementation of a management system to inform and benchmark results, is recommended (European Commission, 2016). Taken together, this framework offers a well-grounded and actionable basis for the hotel industry to adopt more rigorous, indicator-based sustainability performance assessments.

3.2.2. European Ecolabel

Introduced in 1992 by the European Commission, the European Ecolabel is the voluntary label for environmental certification and is based on ISO 14024[11]. The label provides exigent criteria and guidelines depending on the type of business assessed (European Union, 2012). With regards to tourism, regulation EC 287/2003 states the framework for tourist accommodation services (European Commission, 2003). The label aims at identifying products and services with high environmental quality. The corresponding Austrian Ecolabel is the "Österreichisches Umweltzeichen" which was founded in 1990.

[11] ISO 14024:2018 lays down the guidelines and steps for developing environmental labeling initiatives, covering the selection of product categories, environmental criteria, and product functionality attributes. It also outlines the certification process for granting the label.

In Germany the label is called “Blauer Engel” and “Nordic Swan” within the Nordic European countries (European Union, n.D.). Regarding measuring resource consumption, the relevant criteria are divided into optional and mandatory information, focusing on five categories: general management, energy, water, waste, and others. While several consumption monitoring efforts in absolute figures (e.g., sub-metering of energy and water consumption) and creating the basis of an EMS according to EMAS and ISO principles are mandatory (Cirrincione et al., 2020), intensity indicators and audit results could not be revealed.

3.2.3. Global Sustainable Tourism Council Criteria (GSTC)

The Global Sustainable Tourism Council implemented criteria (GSTC) was founded in 2007 with 32 partners, initiated by the United Nation and UNWTO. The accreditation aims at providing a common understanding of sustainable tourism practices and serve as a basis for certification efforts. The criteria are split into four sections (A: sustainable management, B: Socio-economic sustainability, C: Cultural sustainability, D: Environmental sustainability) and derived from analyzing 60 existing sustainability certifications and comments from 1,500 industry experts. Section D of the GSTC criteria is predominantly relevant to this research. Regarding intensity indicators, energy (D1.3 Energy Conversation) and GHG emissions (D2.1 Greenhouse Gas Emissions) are to be monitored by guest/night (EUPGN, COUI, respectively). Similarly, water use (D1.4 Water conversation) and solid waste (D2.4 Solid waste) is measured per guest/night (WUGN, WkgPGN respectively) (GSTC, 2019, 2016).

3.3. Environmental Rating Indices

Rating systems are generally intended to assess and compare companies' sustainability performance. To make benchmarking feasible, rating systems take an additive approach and group key issues, criteria, or themes into sets of topics that could be industry-specific or non-specific. However, it must be acknowledged that most ratings do not target real-estate operational factors but are more tailored to the financial sector and capital markets. Nevertheless, the upcoming section provides a short overview of the most important ESG rating indices in the hotel sector.

3.3.1. MSCI Rating

The MSCI ESG ratings cluster companies according to 35 ESG key issues focusing on the core business as well as specific industry issues. Companies are rated on a AAA (Leader) to CCC (Laggard) scale relative to the performance of the industry peers.

The three pillars of ESG are investigated separately on a weighted average score from 0 to 10. For this research the Environmental pillar, with the theme Climate Change and key issue Carbon Emissions as well as Product Carbon Footprint, the theme Pollution with Toxic Emissions and Waste as well as theme Natural Capital with ESG issue Water Stress can be identified of value (MSCI, 2022). According to the MSCI ESG Industry Materiality Map Hotels, Resorts, and Cruise Lines are within a combined sub-industry stressing the importance of water-related issues (9.2% weighted average) and Carbon emissions (8.9% weighted average) (MSCI, 2023a). Data sources comprise macro data from academic, government, and NGO datasets as well as company financial and non-financial disclosure (MSCI, 2022). Since 1999, MSCI has published an MSCI World Hotels, Restaurants, and Leisure Index. However, ESG metrics are not part of this publication (MSCI, 2023b). With regard to intensity indicators within the environmental pillar, it is revealed that MSCI publishes only a descriptive list of measures taken in each pillar without displaying specific results. Furthermore, the reporting of rating results is not obligatory, i.e., generally not publicly available. As a result, no intensity metrics are displayed in the MSCI index.

3.3.2. Sustainalytics

Netherlands-based company Sustainalytics evaluates companies according to ESG principles in their business operations. Companies are ranked on how well they perform compared to their industry-specific peers (Garz and Volk, 2019). Around 16,000 companies are ranked within the Sustainalytics framework and benchmarked to 42 industries and 138 sub-industries. The company defined 20 material ESG issues (MEI), whereas for this research MEI.7 Emissions, Effluents and Waste, MEI.8 Carbon-Own Operations, MEI.8 Carbon-Products and Services and MEI.20 Resource use is perceived as valuable (Sustainalytics, n.D.). Each company is assigned to one of five risk categories from "Negliglible Risk" (Score 0-9.99 points) to "Severe Risk" (40 and higher points) (Sustainalytics, 2020). Hotel companies are generally within the industry "Consumer Services", revealing that no specific industry cluster exists. Although hotel companies such as Intercontinental Hotels Group (Rating 19.8, Low Risk, 146 out of 479 in industry Consumer Services) (Sustainalytics, 2023a), Accor (Rating 22, Medium Risk, 170 out of 479 in industry Consumer Services) (Sustainalytics, 2023b) or Hyatt (29.7, Medium Risk, 329 out of 479 in industry Consumer Services) (Sustainalytics, 2023c) obtained a rating, relevant intensity indicators or audit results with relations to previous research for the hotel operations could not be found.

3.3.3. CDP Rating

Similarly to other ESG ratings, the Carbon Disclosure (CDP) Rating measures the ESG efforts of companies anywhere in the world and provides a scoring against peers. In 2022, around 15,000 companies reported on their disclosures. The scoring model ranges from A to D-[12], whereas an "F" is given when sufficient information is not provided. Three programs on Climate Change, Water Security, and Forests (CDP, 2023). To allocate sector-specific questions, the questionnaires are divided into 13 industries, "Hospitality" being one of them. The segment "Hotels & Lodging" is part of this industry, being allocated the "Real Estate" questionnaire (CDP, 2022a). A comparison of ratings of the largest hotel companies worldwide reveals (see Table 14) that some only disclose information partly and that "A" ratings are only given in Climate Change (Marriott, IHG and Accor). The Hilton hotel group has not publicly disclosed a CDP rating.

CDP Rating 2022	Hotel Companies					
	Marriott	Hilton	Scandic	IHG	Accor	Hyatt
Climate Change	A	not scored	B	A-	A-	B-
Forests	C	not scored	not scored	F	not scored	not scored
Water Security	B	not scored	not scored	B	B	not scored

Table 14: CDP Rating Hotel Companies
Source: Author's own illustration, data sourced from CDP (2022), Intercontinental Hotels (2022), Marriott International (2021), and Scandic (2022)

With regard to intensity metrics, CDP encourages companies to provide intensity metrics appropriate for business operations. For example, Accor displayed kgCO_2e per available room day (COPAR) (CDP, 2022b), or Hyatt displayed tonsCO_2e per square meter (COUI) (CDP, 2021). However, it has to be acknowledged that intensity metrics are neither uniform nor benchmarkable and are still voluntary in reporting.

3.4. Environmental Benchmarking Tools in the Hotel Industry

As previously noted, there exists a multitude of benchmarking platforms and reporting schemes specifically targeted for the hotel industry. Therefore, only a short overview of the most important ones derived from the scientific and industry literature, as well as recommendations from the UNWTO (UNWTO, 2023).

[12] Level Disclosure D-, D; Level Awareness C-, C; Level Management B-, B; Level Leadership A-, A

3.4.1. Hotel Carbon Measurement Initiative (HCMI)

One of the most widely recognized benchmarking tools in the hotel industry is the Hotel Carbon Measurement Initiative (HCMI), introduced in 2012 by the Sustainable Hospitality Alliance and the World Travel & Tourism Council (WTTC), in collaboration with 23 leading hospitality companies. This initiative provides a standardized methodology for measuring and reporting carbon emissions associated with hotel stays and meetings, thereby promoting comparability and consistency in carbon footprint assessments across the sector. The tool was updated in 2021 to further align with the GHG protocol and is used by 30,000 hotels globally. It is the basis for the Cornell Hotel Sustainability Benchmark Index (CHSB) (see Chapter 3.4.5) as well as Net Zero Methodology for Hotels (see Chapter 3.4.2). HCMI enables hotels to calculate the carbon footprint and is GSTC (see Chapter 3.2.3) recognized as well as uses aspects of the GHG Protocol Standards (see Chapter 3.3.4). Data requirements are basic information such as the number of occupied rooms, total energy consumption for all fuels and electricity, as well as emission factors obtained from international datasets (e.g., IEA, AIB) to calculate corresponding GHG emissions. Data measured are electricity and GHG emissions primarily on Scope 1 and Scope 2 levels. Only outsourced laundry emissions were taken into account within Scope 3 emissions. The tool primarily facilitates internal benchmarking by allowing users to set a baseline year and monitor progress using either absolute values or intensity-based metrics. External benchmarking is also supported through the Carbon and Hospitality Sustainability Benchmark (CHSB). Data entry is conducted via an Excel spreadsheet, ensuring accessibility and ease of use. The tool is available free of charge and can be utilized by hotels globally. For intensity indicators, it employs key reference values such as carbon emissions per occupied room (COPOR) and per unit of floor area (COUI) (Sustainable Hospitality Alliance, 2022a).

3.4.2. Net Zero Methodology for Hotels

Building on the HCMI framework, the Net Zero Methodology for Hotels is a pathway to net zero for hotels by 2050. Net Zero refers to the state where the total amount of GHG emissions emitted into the atmosphere is balanced by the amount removed. This means that any residual emissions must be counteracted through carbon removal measures, such as reforestation, direct air capture, or carbon sequestration (Fankhauser et al., 2022). The main driver for the methodology has been the Paris Agreement (United Nations, 2015b) to reach the 1,5 °C global warming goal by 2050. The methodology is intended to serve as a reference framework for establishing default boundaries and parameters to assess Scope 1, 2, and 3 emissions. The process begins with the selection of a baseline year, which acts as a foundation for tracking progress along the pathway to net zero emissions by 2050. To ensure measurable progress, interim milestones should be established at five-year intervals. In line with the HCMI, the methodology employs carbon output per unit of floor area (COUI) as the primary intensity metric to evaluate developments in resource consumption (Greenview, 2021).

3.4.3. Hotel Water Measurement Initiative (HWMI)

HWMI is a methodology to calculate the water footprint of a hotel which is generally defined as "*the total volume of freshwater used to produce the goods and services consumed by the individual or community or produced by the business*" (Sustainable Hospitality Alliance, 2020, p. 6). The water withdrawal boundaries are consistent with the HCMI framework as well as GRI and CDP and include all activities of the hotel operations (i.e., direct building uses), water purchased from suppliers and extracted on-site by the property as well as outsourced laundry consumption. In addition, the boundaries of water tracking[13] is clearly defined. Within the framework, there is a split of one-third of consumption for guest room use and two-thirds for all other uses based on their relative surface area (though still including hotel rooms). Intensity metrics are predominantly calculated by occupied room (WUOR) and per guest night (WUGN) (Sustainable Hospitality Alliance, 2020).

3.4.4. Hotel Waste Measurement Methodology (HWMM)

This methodology was introduced in 2021 and is intended to develop a common set of waste-related metrics, including food waste differentiated by hotel type and geography. Furthermore, uniform restrictions are set to foster consistent practices across the hotel industry and support industry-level benchmarking. The methodology enables hotels to measure waste across multiple streams, including general waste, recycling, food waste, and hazardous materials. It emphasizes the importance of setting a baseline year and encourages both absolute and intensity-based tracking. The methodology supports internal benchmarking and external comparison. Additionally, it facilitates the identification of key areas for intervention, contributing to long-term waste minimization and improved operational efficiency. Regarding intensity metrics, total waste, including food waste, is measured per square meter (WkgI) as well as the diversion rate (i.e., waste and food waste in%). Additional metrics identified are per occupied room (WkgOR) as well as per guest night (WkgPGN), split by total waste, food waste, and diverted and non-

[13] The following water attributes should be excluded: private space; guest's travel from and to the hotel; embedded water in products; off-site facilities; on-site staff accommodation; water recycled on the property; water discharges; water used at corporate offices; bottled water (Sustainable Hospitality Alliance, 2020)

diverted waste (Sustainable Hospitality Alliance, 2021). Overall, the methodology provides a robust and standardized approach to waste measurement that empowers hotels to track performance and contribute meaningfully to global sustainability objectives.

3.4.5. Cornell Hotel Sustainability Benchmark Index (CHSB)

The largest industry benchmark platform is the *Hotel Sustainability Benchmarking Index of Cornell University* incorporating and displaying HCMI and HWMI results. The database includes about 15,000 hotels with 583 geographies, whereby about 60% of the data material can be geographically assigned to the US market and consists of mostly luxurious, large-volume chain hotels. Regarding data sets, the output data is harmonized in the common units of measurement in kWh (Energy), liters (Water), floor area per square meter, and $kgCO_2e$ (GHG emissions). Furthermore, validity testing to identify outliers of data is performed. Segmentation clustering is done either geographically, by climate zone, or on property level (e.g., asset class, number of stars, market segment, type of hotel). To populate a segmentation a minimum threshold of eight properties is set. In total 12 measures are calculated, whereof eight can be identified as intensity metrics relevant for this research :

- Energy usage: per square meter (EUI, Measure 6), per occupied room (EUPOR, Measure 5)
- GHG emissions: per square meter (COUI, Measure 4), per room (COPAR, Measure 2), per occupied room (COPOR, Measure 3)
- Water usage: per occupied room (WUOR, Measure 8), per square meter (WUOR, Measure 9)

The tool is integrated into an Excel file and allows users to view results segmented by geographic region and hotel category. Results are displayed within the above-explained measures as count (number of hotels), the lowest value found, lower Quartile, mean, median, upper quartile, highest value, and standard deviation (Ricaurte and Jagarajan, 2021). As the tool prohibits an overview of all data, an example report from Germany[14] of the Index 2021 (2019 reporting data set) is illustrated in Figure 10.

[14] Data related to Austria is not represented in the CHSB databank

Cornell Hotel Sustainability Benchmarking Index 2021 : Carbon, Energy and Water

Choose Geography: Germany
Choose Segment: All Hotels
Type: Country
Country: Germany

HOTEL SUSTAINABILITY BENCHMARKING INDEX 2021: ENERGY, WATER, CARBON (2019 Data Set)

2019 CALENDAR YEAR BENCHMARKS								
MEASURE	Count	Low	Lower Quartile	Mean	Median	Upper Quartile	High	SD
MEASURE 1: HCMI Rooms Footprint Per Occupied Room (kgCO2e)	60	2,7	8,9	16,5	13,2	21,1	92,0	13
MEASURE 2: Hotel Carbon Footprint Per Room (kgCO2e)	127	980	2.284	4.237	3.346	5.234	23.133	3.177
MEASURE 3: Hotel Carbon Footprint Per Occupied Room (kgCO2e)	97	2,5	9,3	18,2	15,0	23,6	105,6	14
MEASURE 4: Hotel Carbon Footprint Per Square Meter (kgCO2e)	127	18,4	47,3	72,0	65,4	85,0	230,3	39
MEASURE 4a: Hotel Carbon Footprint Per Square Foot (kgCO2e)	127	1,7	4,4	6,7	6,1	7,9	21,4	4
MEASURE 5: Hotel Energy Usage Per Occupied Room (kWh)	97	17,3	29,0	64,0	54,9	75,3	503,3	60
MEASURE 6: Hotel Energy Usage Per Square Meter (kWh)	127	68,8	146,5	239,6	209,7	289,3	1.003,9	149
MEASURE 6a: Hotel Energy Usage Per Square Foot (kWh)	127	6,4	13,6	22,3	19,5	26,9	93,3	14
MEASURE 7: HCMI Meetings Footprint Per SQM-HR (kgCO2e)	59	0,0020	0,0211	0,0327	0,0296	0,0383	0,1109	0
MEASURE 8: Hotel Water Usage Per Occupied Room (L)	131	70,5	200,0	324,1	270,8	381,2	1.318,9	193
MEASURE 9: Hotel Water Usage Per Square Meter (L)	137	122,4	1.020,8	1.455,0	1.307,3	1.641,9	4.663,2	754
MEASURE 9a: Hotel Water Usage Per Square Foot (L)	137	11,4	94,8	135,2	121,4	152,5	433,2	70
MEASURE 10: HWMI Rooms Footprint Per Occupied Room (L)	8	120,6	215,1	373,0	448,5	486,6	531,3	154
MEASURE 11: HWMI Meetings Footprint Per SQM-HR (L)	8	0,2	0,3	0,4	0,4	0,5	0,5	0
MEASURE 12: Hotel Energy From Renewables (%)	129	0,0%	0,0%	1,9%	0,0%	0,0%	49,1%	0

Figure 10: CHSB Example Germany Results
Source: Cornell University (2021), freely accessible Excel document

3.5. Environmental Benchmarking Tools in Real Estate Operations

As hotels are special-purpose real estate and resource consumption hugely depends on operational factors, a short research on environmental certification of real estate operations and its application in the hotel industry is presented.

3.5.1. Carbon Risk Real Estate Monitor (CRREM)

The CRREM initiative translates the Paris Agreement (United Nations, 2015b) to limit global warming to 1.5 °C by 2050 into asset class-specific trajectories. The free-of-charge software is in Excel format[15] and illustrates the pathway to net zero by 2050 and quantifies the risk of assets being stranded due to regulatory incompliance (so-called “transition risk”, see Figure 11) (Recourt et al., 2023).

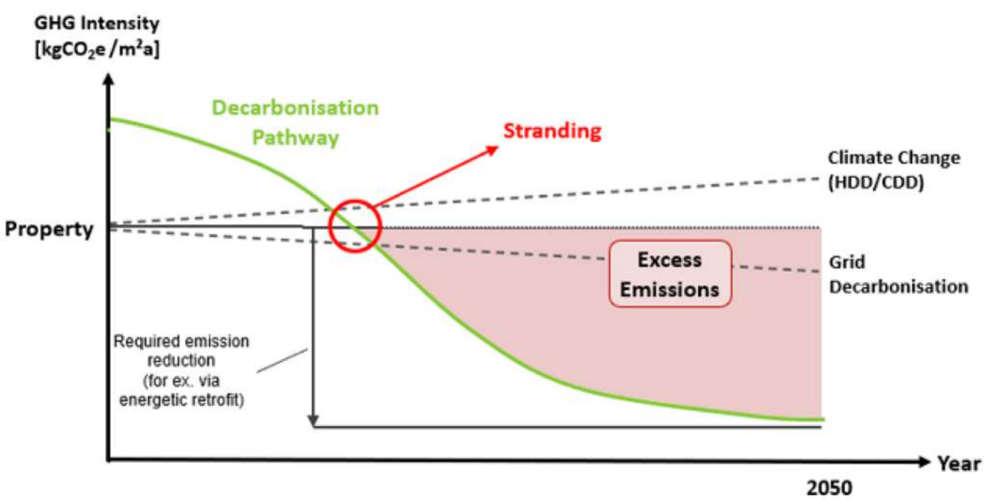
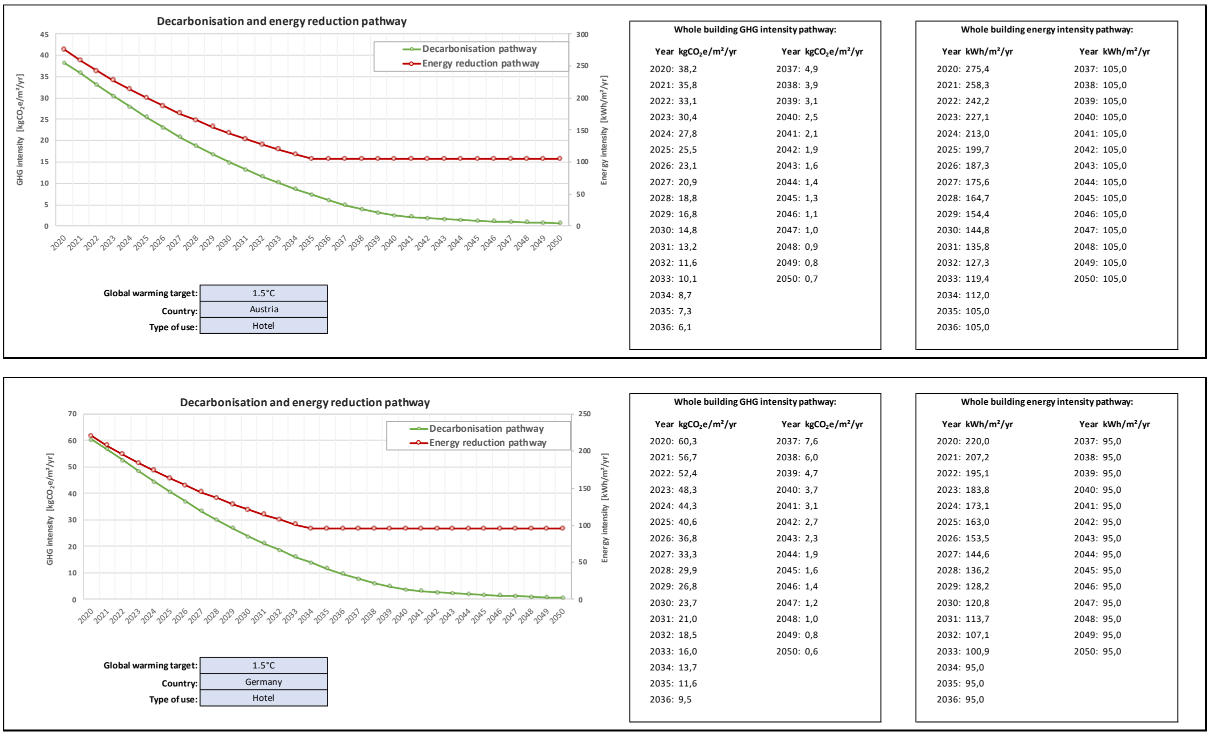


Figure 11: CRREM Stranding Diagram
Source: Recourt et al. (2023, p. 6)

[15] The tool can be downloaded under https://www.crrem.eu/tool/

The diagram illustrates the relationship between GHG intensity and time, emphasizing the need for emission reductions in the property sector. The decarbonization pathway (green line) represents the ideal reduction trajectory while stranding (red circle) marks a critical point where emissions exceed targets. Excess emissions (red shaded area) highlight the gap if reductions are insufficient. Grid decarbonization and climate change impacts (dashed lines) indicate external factors affecting emissions. Besides the stranding diagram, the CRREM tool generates the energy reduction pathway, costs of energy and carbon emissions, costs of retrofitting to comply with the pathway, individual retrofit and payback scenarios as well as energy and carbon intensity with and without retrofit measures (Recourt et al., 2023). The tool can extrapolate, e.g., energy consumption, to floor areas for which energy consumption data is unavailable. Furthermore, weather normalization efforts were integrated within the latest version of the tool. Specific industry targets are available; the intensity metric is generally evaluated by floor area (i.e., EUI, COUI). In Figure 12 targets for the industry "Hotels" within Austria and Germany are displayed.



Austria – Whole building GHG intensity pathway:

Year	$kgCO_2e/m^2/yr$	Year	$kgCO_2e/m^2/yr$
2020:	38,2	2037:	4,9
2021:	35,8	2038:	3,9
2022:	33,1	2039:	3,1
2023:	30,4	2040:	2,5
2024:	27,8	2041:	2,1
2025:	25,5	2042:	1,9
2026:	23,1	2043:	1,6
2027:	20,9	2044:	1,4
2028:	18,8	2045:	1,3
2029:	16,8	2046:	1,1
2030:	14,8	2047:	1,0
2031:	13,2	2048:	0,9
2032:	11,6	2049:	0,8
2033:	10,1	2050:	0,7
2034:	8,7		
2035:	7,3		
2036:	6,1		

Austria – Whole building energy intensity pathway:

Year	$kWh/m^2/yr$	Year	$kWh/m^2/yr$
2020:	275,4	2037:	105,0
2021:	258,3	2038:	105,0
2022:	242,2	2039:	105,0
2023:	227,1	2040:	105,0
2024:	213,0	2041:	105,0
2025:	199,7	2042:	105,0
2026:	187,3	2043:	105,0
2027:	175,6	2044:	105,0
2028:	164,7	2045:	105,0
2029:	154,4	2046:	105,0
2030:	144,8	2047:	105,0
2031:	135,8	2048:	105,0
2032:	127,3	2049:	105,0
2033:	119,4	2050:	105,0
2034:	112,0		
2035:	105,0		
2036:	105,0		

Germany – Whole building GHG intensity pathway:

Year	$kgCO_2e/m^2/yr$	Year	$kgCO_2e/m^2/yr$
2020:	60,3	2037:	7,6
2021:	56,7	2038:	6,0
2022:	52,4	2039:	4,7
2023:	48,3	2040:	3,7
2024:	44,3	2041:	3,1
2025:	40,6	2042:	2,7
2026:	36,8	2043:	2,3
2027:	33,3	2044:	1,9
2028:	29,9	2045:	1,6
2029:	26,8	2046:	1,4
2030:	23,7	2047:	1,2
2031:	21,0	2048:	1,0
2032:	18,5	2049:	0,8
2033:	16,0	2050:	0,6
2034:	13,7		
2035:	11,6		
2036:	9,5		

Germany – Whole building energy intensity pathway:

Year	$kWh/m^2/yr$	Year	$kWh/m^2/yr$
2020:	220,0	2037:	95,0
2021:	207,2	2038:	95,0
2022:	195,1	2039:	95,0
2023:	183,8	2040:	95,0
2024:	173,1	2041:	95,0
2025:	163,0	2042:	95,0
2026:	153,5	2043:	95,0
2027:	144,6	2044:	95,0
2028:	136,2	2045:	95,0
2029:	128,2	2046:	95,0
2030:	120,8	2047:	95,0
2031:	113,7	2048:	95,0
2032:	107,1	2049:	95,0
2033:	100,9	2050:	95,0
2034:	95,0		
2035:	95,0		
2036:	95,0		

Figure 12: CRREM Targets Austria and Germany
Source: CRREM (2024), freely accessible online tool

The comparison between Austria and Germany under the Long-Term Transition (LTT) scenario for the hotel sector reveals similar progress in energy efficiency but differing outcomes in carbon reduction. Both countries show a steady decline in EUI from over 220 kWh/m² in 2020 to approximately 100 kWh/m² by 2050, reflecting consistent efforts to improve energy performance in hotel buildings. However, carbon emissions pathways diverge more significantly. Austria reduces emissions from 38.2 $kgCO_2e/m^2$ in 2020 to 0.7 $kgCO_2e/m^2$ by 2050, whereas Germany starts at a higher baseline of 60.3 $kgCO_2e/m^2$ but achieves a more ambitious reduction to just 0.6 $kgCO_2e/m^2$. This indicates that Germany's pathway relies more heavily on decarbonizing its energy supply alongside efficiency measures. The data underscores the importance of combining operational improvements with broader systemic energy transitions to meet climate goals in the hospitality industry.

3.5.2. Global Real Estate Sustainability Benchmark (GRESB)

The GRESB framework provides standardized ESG data of real estate assets and covers more than 1,8000 property companies, funds, developers, and real estate investment trusts (REITs) with a total of USD 8.6 trillion asset value. The methodology is consistent with international reporting frameworks such as GRI. The scoring model is based on three components – Management, Performance, and Development, whereas the Performance section covers Energy, GHG, Water, and Waste consumption. Scoring is granted whether data coverage is existent as well as Like-for-like performance improvement is done (GRESB, 2023). Although the GRESB framework is a well-known industry standard and differentiation in the property type "hotel" exists, GRESB displays only scores in the respective fields (see Figure 13). As a result, no relevant intensity indicator could be identified.

Figure 13: GRESB Report Example
Source: GRESB (2022, p. 3)

3.5.3. BREEAM In-Use

BREEAM In-Use is a framework to assess the operational sustainability performance of existing non-domestic assets such as care homes, hotels, and office buildings. The rating is split between asset performance (Building-related) and management performance (Operations-related), comprising 11 environmental categories. Relevant categories for this research are Energy, Water, Resources (Waste related) and Pollution. A score is given, whereas above 85% is classified as Outstanding (6-star rating), and below 10% is classified as Unclassified (no star rating). The framework comprises 13 asset types with 45 asset sub-types. Hotels are their own sub-type under the Hospitality asset type. While within the framework sub-metering of resource consumption is recommended, no intensity indicators could be revealed (BREEAM, 2020). Researchers generally agree that having a BREEAM certificate in a hotel building contributes to a positive sustainability performance (Serrano-Baena et al., 2021). When screening the Technical Manual it becomes evident that attributes are more related to retrofit and resource-efficient equipment such as water-efficient toilets (WAT 02), and water-efficient showers (WAT 05) (BREEAM, 2020). With regard to intensity metrics, no valid or applicable indicators are identified in the context of this research.

3.6. Analysis of Environmental Reporting by the largest Hotel Companies

Following the introduction of legislative standards and the most important reporting and benchmarking schemes, the application within the largest hotel companies worldwide is investigated and analyzed below. Moreover, it is emphasized that leading hotel companies have a leading role in promoting sustainability (Jones et al., 2014). The upcoming section analyzes efforts of displaying resource consumption targets and intensity metrics used in the environmental reporting of the largest hotel companies worldwide. Nevertheless, research indicates that non-financial reporting by large hotel chains is not uniformed, making comparisons nearly impossible (Legrand et al., 2013). As the largest hotel company in the world, as of 2022, **Marriott International** (hereafter abbreviated Marriott) manages 7,989 properties with a total portfolio of 1.5 million rooms. The loyalty program Marriott Bonvoy has around 160 million members. In its Serve 360 annual report, the ESG progress of the company is displayed. Regarding environmental issues, the company aims at achieving net zero by 2050, already achieving a COUI reduction of 25.6% from 2016 to 2021. However, it has to be acknowledged that this metric is highly affected by the impact of the Coronavirus pandemic. By 2025, 30% of total energy consumption is targeted to come from renewable sources. Water consumption was measured by occupied room (WUOR), averaging 880 liters, which is generally higher than the IHG Hotels & Resorts portfolio (WUOR 617,7). Despite absolute figures, waste-related metrics have not been illustrated (Marriott International, 2022). Reducing waste impacts is anticipated by phasing out single-use plastics or predominantly buying products that can be reused, recycled, composted, or donated. 30% of the hotel properties of Marriott are certified by recognized sustainability standards (e.g., LEED, BREEAM) (Marriott International, 2022).

Hilton Worldwide (hereafter abbreviated Hilton), as the second-largest hotel operator, has 7,165 hotels with around 1.1 million rooms in its portfolio and issues an annual ESG report (Hilton Worldwide, 2022a). Likewise to Marriott, Hilton strives towards net-zero by 2050. In 2018, specific goals (e.g., cut managed emissions by 75%, cut water as well as landfilled waste intensity by 50%) by 2030 and continuously tracked via a publicly available goal tracker (Hilton Worldwide, 2022b). To measure, manage, and report environmental data, the hotel company uses LightStay, which is globally recognized by the GSTC, ISO 9001, ISO 14001, and ISO 50001 (Hilton Worldwide, n.D.). Hilton reports Scope 1 to Scope 3 emissions in detail. Water-related figures are water consumption and water withdrawal, and within waste-related figures, total waste, landfilled waste, waste diverted, as well as waste diversion rate. Intensity metrics are generally reported by floor intensity (EUI 241.4 kWh, WUI 472 liters, WkgI 5.1 kg, COUI 82.9 kg) and are consequently slightly lower than the figures reported by Marriott International.

IHG Hotels & Resorts (hereafter abbreviated IHG) has a total system size of 6,164 hotels with around 912,000 rooms with a geographical focus on Americas (57% of total rooms) and EMEAA (25% of total rooms). The main targets are to reduce GHG emissions (Scope 1-3[16]) by 46% by 2030 from the 2019 baseline year and to achieve net zero by 2050. Reporting of energy-related figures is done by displaying different energy sources. Within water consumption emphasis is laid on consumption of areas with water scarcity. In waste-related figures, general waste, food waste, recycled waste as well as composted absolute figures are displayed. Regarding environmental metrics, to the contrary of Marriott and Hilton, IHG generally reports results by occupied rooms within the energy (EUPOR 72.6 kWh), GHG (COPOR 33.4 kgCO_2e), and water (WUOR 617.7 liters) section (Intercontinental Hotels, 2022b, 2022a). Therefore, a comparison of reporting figures with other hotel companies is limited.

The **Accor Group** (hereafter abbreviated Accor), with its 5,400 hotels and around 800,000 rooms, is predominantly focused on the European market (43% of total rooms). As well as other hotel groups, Accor aims to be net-zero by 2050 (Accor Group, 2022). Although committing to ESG topics, Accor has not released an internal ESG report to date. Though, the official CDP and Sustainalytics report has been publicly available stating absolute environmental figures on a headline basis (CDP, 2022b; Sustainalytics,

[16] Emissions scope definitions can be found in the IHG Databook 2022 on page 5 (Intercontinental Hotels, 2022a)

2021). The non-financial reports do not contain any relevant environmental intensity indicators, highlighting a significant gap in the disclosure of measurable sustainability performance metrics.

Hyatt Hotels Corporation (hereafter abbreviated Hyatt) is another major hotel company. Their portfolio consists of around 1,300 hotels with a total of 300,000 rooms (Hyatt, 2022). In 2021, the World of Care – its own ESG platform was launched. Similar to other hotel companies, environmental goals were set to be achieved in 2030 (e.g., reduce Scope 1 and 2 emissions by 27.5% compared to 2019). In general, environmental data are not displayed in detail as with Scandic, IHG or Hilton. While in the reports, the measurement is indicated to be benchmarked by square meter; results are displayed in a one-page document (Hyatt, 2021b). Especially within WUI there is some discrepancy with a result of 1,970.3 liters compared to the results within the academic literature review as well as other industry data (e.g., Hilton WUI 472 liters).

A European hotel company that has been numerously recognized for caring about environmental issues since the early 2000s is the **Scandic Hotel Company** (hereafter abbreviated Scandic), measuring basic environmental data since 1996 and being certified by Nordic Swan Ecolabel in 1999 (Bohdanowicz and Martinac, 2007). Currently, 76% of all hotels receive the label. Predominantly located in Northern Europe, Scandic operates 270 hotels with about 56.000 hotel rooms. The main environmental targets are to reduce GHG emissions by the square meter (COUI) by 50% in 2030 with a base year of 2019 (6.3 kgCO_2e COUI). As of 2022, the reduction was already by 29%. Scope 1 and Scope 2 emissions have been reported since 2015; in 2022, reporting of Scope 3 was initiated. Scope 1 and Scope 2 energy emissions are listed in detail within the environmental data section. Regarding intensity metrics, EUI is used without displaying results, however, arguing that consumption has been reduced by 8% compared to 2019. Regarding water consumption, Scandic is using a reporting by guest night (WUGN) which is in accordance with the factor analysis done in the scientific literature review. Currently, the mean average of all hotels possesses a WUGN of 170 liters, which is a reduction of 7% compared to the base year of 2019. While waste volume split by method of disposal differentiated into hazardous and non-hazardous as well as per type of waste are listed in total figures, no measurable metrics are recorded in the report (Scandic, 2022).

Table 15 compares and contrasts main findings of the environmental efforts of the largest hotel companies. When collecting data, most companies use their own bespoke proprietary measurement systems. Regarding external rating efforts, the hotels mentioned above companies use many different industry standards, whereas the leading rating indices can be identified as MSCI, Sustainalytics, and CDP. Reporting standards are predominantly SASB and GRI interrelated due to the argued considerable overlap between the two schemes (GRI and SASB, 2021). This finding is in accordance with the research findings of Halmi and Poldrugovac (2022) and Lau et al. (2021). With total energy consumption and water withdrawal, input metrics are in line with the scientific research. Waste input metrics are not uniform, revealing that harmonization is necessary. All hotel companies report Scope 1 and Scope 2 emissions with (partly) consideration of Scope 3 emissions. This is in accordance with other industries in the finance, fashion, and events sector around the difficulties posed by measuring Scope 3 emissions and apportioning responsibilities to the respective supply chain (UNWTO, 2023).

	Hotel Companies					
	Marriott	**Hilton**	**Scandic**	**IHG**	**Accor**	**Hyatt**
ESG report available	yes	yes	yes	yes	no	yes
Detailed consumption data displayed	yes	yes	yes	yes	no	no
Input variables Energy	Total energy consumption	Total energy consumption	Total energy consumption divided into propane, natural gas, biofuel, heating oil, gasoline, district heating (Scope 2), district cooling (Scope 2)	Total energy consumption divided into fuel, electrizity, cooling, heat, steam, renewables, electrizity produced, other	-	Total energy consumption
Input variables Water	Total water consumption	Total water consumption, water withdrawal	Total water consumption	Total water consumption, displaying properties consumption of areas with water scarcity	-	Total water consumption
Input variables Waste	-	Total waste, landfilled waste, waste diverted from landfill	Total weight per method of disposal (reuse, recycling, energy recovery, combustion, landfill) divided by hazardous and non-hazardous, total weigh per type of waste (paper, glass, metal, plastic, other)	Total waste split into general waste, food waste, recycling, composting	-	-
GHG emissions reported	Scope 1, Scope 2, partially Scope 3	Scope 1, Scope 2, partially Scope 3	Scope 1, Scope 2, partially Scope 3	Scope 1, Scope 2, Scope 3	Scope 1, Scope 2, partially Scope 3	Scope 1, Scope 2, partially Scope 3
GHG emissions standard					Greenhouse Gas Protocol	
Ecolabel / Rating Indices	MSCI	Dekra Assurance Statement, MSCI	Nordic Swan, partly CDP	S&P SAM, Global (DJSI), CDP, MSCI, Sustainalytics, FTSE4Good, ISS ESG, Wdi	Sustainalytics, MSCI, FTSE4Good, Euronext, partly CDP, VIGEO	partly CDP
Properties certified	-	-	76%	-	-	-
Reporting Scheme	TCFD, SASB and GRI	SASB, GRI, LightStay, GSTC	-	SASB and GRI	SASB	SASB and GRI

Table 15: Rating Indices and Reporting Schemes of International Hotel Companies
Source: Author's own data

3.7. Discussion and Conclusion of Existing Initiatives

Several researchers have highlighted the fast-paced development of sustainability disclosure and legislative standards (Hummel and Jobst, 2024; Stolowy and Paugam, 2023) and the low probability of convergence in sustainability reporting (Baboukardos et al., 2023). Elaborating on different legislative standards and auditing schemes and consequently comparing them with current practical practices in the hotel industry reveals inconsistencies and gaps. Although CSRD and ESRS are not obligatory yet, it appears that companies are still lacking uniformity and must comply with emerging legislative standards. Although attempts for harmonizing sustainability reporting are still very low within the largest hotel companies in the world (Halmi and Poldrugovac, 2022), there is a lack of regulatory indications regarding the content and layout to be reported (Torelli et al., 2020). Thus, companies choose the manner of presentation independently, which results in highly diverse reporting strategies in business in general (Jose, 2017; Kinderman, 2020) as well as in the tourism industry specifically (Legrand et al., 2013; UNWTO, 2023; Jones et al., 2014). Reported intensity metrics and KPIs, as well as audit results, are not aligned and often results are highly diverse. This is further highlighted by the study of Jones et al. (2014, p. 5) critically summarizing that sustainability efforts of the largest hotel companies "*are couched within existing business models centered on continuing growth, and that as such the global hotel industry is currently pursuing a weak rather than a strong model of sustainability.*" Furthermore, as highlighted by Legrand et al. (2013) reporting, metrics are still not uniform to one industry standard, resulting in additional recalculation efforts to make data comparable.

Existing sustainability frameworks and industry initiatives provide a strong foundation for the further development of resource intensity metrics in the hotel sector. While the ESRS currently emphasize revenue-based denominators, they offer detailed input data and acknowledge the need for sector-specific intensity ratios. Similarly, the EMAS regulation promote performance-based reporting using standardized indicators such as EUI, WUGN, and WkgPGN, offering comparability across tourism accommodations. Voluntary initiatives further strengthen this foundation. The GSTC outlines environmental performance indicators based on guest-related metrics, while the HCMI, adopted by over 30,000 hotels, standardizes Scope 1 and 2 emissions reporting per occupied room and per floor area. Complementary tools like the HWMI and the Sustainable Hospitality Alliance's waste tracking methodology already offer clearly defined boundaries and standardized metrics for water and waste performance. However, their full potential depends on broader adoption within the industry. Together, these initiatives establish a robust and actionable framework that, if more widely implemented, could significantly support the development of sector-specific standards and enable more consistent, operationally meaningful benchmarking across the hotel sector.

Drawing on the encountered findings and EGWW intensity metrics identified in the SLR analysis (see Table 12), Table 16 presents the metrics used in the non-financial reporting of the analyzed hotel companies. An “x” denotes the inclusion of a particular intensity metric in the respective company’s environmental reporting.

Metrics used		**Hotel Companies**					
	Metrics abbreviation	**Marriott**	**Hilton**	**Scandic**	**IHG**	**Accor**	**Hyatt**
	EUI	x	x	x			x
	EUPGN						
Energy	EUPOR				x		
	EUPAR						
	EUPAB						
	WUGN			x			
	WUI		x				x
Water	WUOR	x			x		
	WUId						
	LGN						
	WkgPG						
	WkgPGN						
Waste	WlPG						
	WkgI		x				
	WlPG						
	COPGN					x	
	COUI	x	x	x			x
GHG	COPAR						
	COPAB						
	COPOR				x		

Table 16: Intensity Indicators used by International Hotel Companies
Source: Author’s own data

When comparing the metrics with those identified in the academic analysis, no additional metrics are found. However, not all of the identified metrics are used by the companies. Whereas most of the companies report their energy and GHG consumption on a per floor area variable (EUI, COUI), water metrics are generally related to a per person reference variable. Similar to the scientific literature review, waste reporting figures are also within the reporting efforts of the largest hotel companies and are primarily descriptive, without measuring with specific intensity indicators or displaying comparable audit results. Therefore, reliable group-wide waste intensity metrics are currently not displayed.

Based on the above listed intensity metrics, Table 17 provides an overview of the reported consumption figures. However, some reports do not include numerical data, which results in certain fields being left blank. As metrics are not uniform, conversions are calculated (e.g., MJ in kWh, tons in kg, cubic meters in liter). While the EUI audit results remain consistent across the reported figures (e.g., Marriott EUI 276.9 kWh, Hyatt EUI 271.1 kWh), water consumption varies significantly among different hotel companies, suggesting inconsistencies in measurement boundaries. Similar discrepancies are revealed when analyzing COUI. For example, while Marriott (COUI 93.7 kg), Hilton (COUI 82.9 kg) and Hyatt (COUI 97 kg) illustrate comparable figures, Scandic reported a COUI of 9 kg.

Audit Results		Hotel Companies					
	Metrics abbreviation	Marriott	Hilton	Scandic	IHG	Accor	Hyatt
Energy (in kWh)	EUI	276.9	241.4	not reported			271.1
	EUPGN						
	EUPOR				72.6		
	EUPAR						
	EUPAB						
Water (in liters)	WUGN			170.0			
	WUI		472.0				1970.3
	WUOR	880.0			617.7		
	WUId						
	LGN						
Waste (in kg)	WkgPG						
	WkgPGN						
	WlPG						
	WkgI		5.1				
	WlPG						
GHG (in $kgCO_2e$)	COPGN					not reported	
	COUI	93.7	82.9	9.0			97.0
	COPAR						
	COPAB						
	COPOR				33.4		

Table 17: Audit Results International Hotel Companies
Source: Author's own data

When comparing the results with the findings from the SLR (see Table 8), the reported EUI figures of the analyzed hotel companies exhibit moderate alignment. For instance, the EUI reported by Marriott (276.9 kWh) closely corresponds to the SLR findings based on a sample of 2,280 hotels (273.9 kWh). Similarly, regarding water consumption, the WUOR values are consistent with those reported in Ricaurte (2011) study, which recorded an average consumption of 807.7 liters. However, beyond these indicators, the remaining reported figures are inconsistent and lack standardization, making cross-comparisons difficult. Moreover, not all relevant environmental intensity indicators are included in the non-financial reports, indicating a critical gap in the disclosure of quantifiable sustainability metrics.

In conclusion, ESG reporting among the world's largest hotel companies is markedly inconsistent, failing to provide a clear pathway for emission reduction as required by the ESRS. In terms of intensity metrics concerning EGWW a definitive path forward remains elusive. The analysis of the ESRS directive revealed that, despite resource consumption per net revenue, intensity metrics are not obligatory to report. However, it becomes evident that schemes tailored to the hotel industry (e.g., HCMI, GSTC, EMAS, HWMI) and reporting practices of large hotel companies are predominantly using a user-centric approach when reporting (i.e., per occupied room, per guest) rather than per floor area benchmarking. This reveals a significant research gap regarding the development of standardized intensity metrics that align both with regulatory requirements and industry best practices. A more detailed discussion of the identified research gaps is presented in Section 4.1.

4. Methodology

The following sections present the systematic methodology employed to address the research questions of this thesis and to identify the most effective strategies for their resolution. Following a thorough examination of research gaps and the innovative aspects of the thesis topic, the exploration delves into qualitative and quantitative research methodologies. During the initial stages of data collection, various data analysis techniques are carefully evaluated and considered. This chapter concludes with a comprehensive overview of the research design and method selection, strategically aligned to achieve the research objectives.

4.1. Research Gaps and Novelty of Research Work

Although research on resource benchmarking in the hotel industry has advanced in recent years, several notable research gaps remain. First, the SLR reveals a lack of consistency in applied intensity metrics, particularly in the measurement of GHG emissions and waste. This gap is compounded by methodological inconsistencies, such as varying system boundaries and unclear reference units, which hinder comparability across studies. Additionally, intensity metrics tailored to the hotel industry remain absent from the ESRS framework, highlighting the need for industry-specific standardization in sustainability reporting. Second, a significant gap exists in data availability for Germany and Austria, as resource consumption benchmarks for Central European hotels are currently unreliable due to limited and fragmented datasets. Existing studies predominantly focus on large-scale, chain-affiliated hotels in Asia and North America, leaving the highly fragmented, often small-scale hotel market in Central Europe underexplored. Third, while previous research identifies key operational, physical, and external determinants of resource consumption, it also demonstrates significant unexplained variance in the regression models. This suggests the presence of additional influencing factors, which have yet to be systematically captured or quantified. Furthermore, existing environmental benchmarks lack clarity, with inconsistent clustering techniques across various standards, making cross-comparisons challenging. This study seeks to address this gap by identifying resource consumption patterns and key influencing factors specific to the researched region, thereby contributing to more accurate and regionally relevant benchmarks and consumption patterns.

Therefore, this work introduces several novel contributions to both academic research and industry practice. First, it systematically reviews existing literature, encompassing both academic studies and industry publications, to identify key gaps and trends. Second, the benchmarking model integrates recent regulatory developments, particularly within the frameworks of the Green Deal and ESG Taxonomy, ensuring alignment with the latest sustainability standards. Third, the study explores a geographical setting in Central Europe at an unprecedented depth, addressing a region that has been largely overlooked in previous research. Additionally, the dataset focuses on properties in a continental climate, a factor rarely examined in similar studies, providing valuable insights into the specific environmental and operational challenges faced by hotels in such regions. Fourth, the study employs a mixed method research approach, analyzing the research field from multiple perspectives to generate more comprehensive and nuanced findings. This combination of qualitative and quantitative methodologies enhances the robustness of the analysis and contributes to a deeper understanding of resource benchmarking in the hotel industry. Fifth, the research advances the discussion on resource efficiency benchmarking by integrating both qualitative insights (e.g., industry practices and expert perspectives) and quantitative analysis (e.g., statistical modeling and data-driven evaluations). Finally, the inclusion of a large dataset comprising approximately 300 hotels strengthens the reliability of the study's findings, enabling the development of robust regression models for predicting energy and water consumption. These insights contribute to establishing more accurate benchmarks for the hotel industry, addressing critical gaps in sustainability performance assessment. To summarize, this study refines benchmarking methodologies, enhances the integration of sector-specific intensity metrics into regulatory frameworks, and establishes a more systematic approach to resource benchmarking in the hotel sector.

4.2. Research Questions and Hypotheses

Research questions must express the substantive project goal and explain 'what' the research is about (Saunders et al., 2012). Thus, research questions explain what one wants to know, from whom, in which geographical and socio-cultural context (Alvesson and Sandberg, 2013). A common criterion for what defines a research question is that it must be 'researchable' and 'investigable' (Savin-Baden and Major, 2013; White, 2009) as well as precise (Alvesson and Sandberg, 2013). From the initial literature review identifying main intensity metrics in the field of EGWW for the hotel industry and its dependent physical and operational variables, the following vital questions emerge in summary:

Researchable questions deriving from the literature review chapters:

- Which of the identified intensity metrics are actively used within the German and Austrian hotel industry?
- Are the intensity metrics easily collectible and measurable for benchmarking?

- Do audit results of EGWW intensity metrics of German and Austrian hotels differ from previous study results in other geographic areas?
- What are the most convenient reporting units in each category?
- What is an appropriate reporting/measurement frequency?
- What physical and operational variables influence EGWW intensity metrics of hotels located in Germany and Austria?
- According to which attributes should hotels be clustered to achieve a valid peer group?
- Which operational and physical characteristics of hotels significantly correlate with resource consumption?
- Can a reliable model be created to predict total energy and water consumption for a hotel of distinct characteristics?

The following core hypotheses can be derived from the central research questions, which are evaluated using a mixed research approach consisting of a qualitative and quantitative phase.

4.2.1. Core Hypotheses: Qualitative Research Phase

Deriving from the existing literature from academic as well as industry-specific sources, the following hypotheses are evident within the in-depth qualitative investigation:

Hypothesis 1:

H_0: In environmental reporting, it is hypothesized that energy consumption, water usage, waste generation, and GHG emissions figures are perceived as critical metrics, forming the cornerstone of sustainability and corporate responsibility for the German and Austrian hotel industry.

Hypothesis 2:

H_0: Stakeholders in the German and Austrian hotel industry have a high level of awareness of the EU Taxonomy and its associated reporting obligations (CSRD, ESRS).

Hypothesis 3:

H_0: Intensity metrics measuring factors related to EGWW are consistently and uniformly identified and applied across the German and Austrian hotel industry.

Hypothesis 4:

H_0: The data required to construct intensity metrics, particularly in day-to-day hotel property operations, can be easily collected without significant resource or time constraints.

Hypothesis 5:

H_0: The intensity metric used for benchmarking energy resource consumption in the German and Austrian hotel industry measures primary energy demand per square meter, expressed in kilowatt-hours (kWh).

Hypothesis 6:

H_0: The intensity metric for benchmarking water resource consumption in the German and Austrian hotel industry is the assessment of total water consumption per occupied room, measured in liters.

Hypothesis 7:

H_0: The intensity metric to benchmark waste resources in the German and Austrian hotel industry is total waste per guest, measured in kg.

Hypothesis 8:

H_0: The intensity metric to benchmark GHG consumption in the German and Austrian hotel industry is carbon footprint per square meter, measured in kgCO_2e *and split in Scope 1,2, and 3.*

Hypothesis 9:

H_0: Non-financial sustainability reporting is typically conducted on an annual basis, aligning with financial reporting obligations in most regulatory frameworks.

Hypothesis 10:

H_0: Hotels in Germany and Austria are more inclined to utilize external and internal benchmarking when assessing and measuring environmental factors.

Hypothesis 11:

H_0: To establish a valid peer group for clustering, it is necessary to differentiate and categorize entities based on both their physical attributes and operational characteristics.

4.2.2. Core Hypotheses: Quantitative Research Phase

Following the findings of the qualitative phase and the formation of associated intensity metrics and influencing factors for hotels in Germany and Austria, the following core hypothesis for quantitative analysis derive:

Hypothesis 12:

H_0: There is a positive correlation between energy and water audit results and the quality level of a hotel.

Hypothesis 13:

H_0: There is a positive correlation between environmental resource consumption and the type of F&B service of a hotel.

Hypothesis 14:

H_0: Higher average room prices positively correlate with total energy and water consumption and hotel intensity metrics.

Hypothesis 15:

H_0: There is no significant difference in energy and water efficiency between older and newer hotel buildings.

Hypothesis 16:

H_0: Hotels that adopt hardware retrofitting efforts experience a measurable decrease in resource consumption compared to those that do not.

Hypothesis 17:

H_0: Resource consumption patterns are similar between urban and rural hotels.

Hypothesis 18:

H_0: Hotels that outsource their laundry services exhibit lower resource consumption compared to hotels that manage laundry in-house.

Hypothesis 19:

H_0: Total resource consumption and associated intensity metrics are the same between hotels with dedicated MICE areas and hotels without such facilities.

Hypothesis 20:

H_0: Total resource consumption and associated intensity metrics are the same between hotels with dedicated wellness areas and hotels without such facilities.

Hypothesis 21:

H_0: There is no significant difference in resource consumption between chain-affiliated and independent hotels.

Hypothesis 22:

H_0: Hotels equipped with air-conditioning systems consume more electricity than hotels without air-conditioning systems due to the additional electricity requirements for cooling and climate control.

Hypothesis 23:

H_0: Regression models for energy consumption are reliable in predicting total resource consumption in the German and Austrian hotel industry.

Hypothesis 24:

H_0: Regression models for water consumption are reliable in predicting total resource consumption in the German and Austrian hotel industry.

Hypothesis 25:

H_0: There is a statistically significant difference in total energy consumption based on at least one of the independent variables (star rating, hotel size, or location) or their interactions.

Hypothesis 26:

H_0: There exists an energy- and water-consumption nexus in resource consumption in hotel real estate.

4.3. Research Methodology

Environmental metrics for the hotel industry is a multidisciplinary field; the research carried out tends to be complex, and no single approach is suitable for all studies as different approaches and techniques may be used (Sinkovics et al., 2008). In addition, a methodology is appropriate that is not primarily oriented toward existing hypotheses, but rather works exploratively, i.e., that pursues an initial orientation of a thematically new research field (Bogner et al., 2005) and is well-suited for complex social issues (Leedy and Ormrod, 2016). Research methodology is defined as fundamental research assumptions encompassing the philosophical framework underpinned by philosophical justifications (Creswell and Plano Clark, 2018). A thorough discussion of the research approach is necessary to increase the validity of social research. Therefore, this chapter is tangled around the methodology of the empirical part of this dissertation, mainly focusing on the ontological and epistemological elements discussing research design, data analysis techniques, and the overall procedure of the research flow.

4.3.1. Research Approach

Two distinct paradigms prevail when discussing the 'right' research approach for academic research: interpretivism and positivism (Rahman, 2016). The positivistic researcher's view comprises quantifiable data which is objectively measurable. Conversely, the interpretivism paradigm argues that reality is socially constructed, not measurable and subjective (Corbetta, 2003; Khan, 2014; Denzin and Lincoln, 2013). Therefore, a general differentiation between numeric (quantitative) and non-numeric (qualitative) data can be made, and the researcher must decide which is best to attain the research goal (Creswell, 2013; Pratt et al., 2020). Quantitative research provides validity and reliability; qualitative studies provide in-depth data on subjective interpretations of a social phenomenon (Saunders et al., 2012). The upcoming section will outline and discuss both concepts in further detail.

4.3.1.1. Qualitative Research

Qualitative research can be defined as an "*iterative process in which improved understanding to the scientific community is achieved by making new significant distinctions resulting from getting closer to the phenomenon studied*" (Aspers and Corte, 2019, p. 155). Others such as Corbin and Strauss (1990, p. 17) define qualitative research as *"any kind of research that produces findings not arrived by means of statistical procedures or other means of quantification"*. Thus, the focus lies on data collection and data analysis techniques (categorizing and decoding data) with non-numerical and non-standardized data, causing the research process to emerge and alter during the data collection (Saunders et al., 2012). Qualitative data can be collected by conducting interviews, making observations, or researching relevant archives or records, as well as intangible, including memories and inspirations (Bhattacharya, 2017; Zohrabi, 2013). The research structure is generally flexible, allowing adaptations along the process (Basias and Pollalis, 2018; Maxwell, 2013) and refining research questions to be continuous throughout the study (Darlington and Scott, 2020). Furthermore, several authors acknowledge that qualitative research is better suited to under-researched topics within the existing body of knowledge and helps to generate theory rather than to test it (Bryman, 1984; Daniel, 2016; Ji et al., 2019; Pratt, 2009) and 'explore' the phenomena (Hair et al., 2024). Table 18 summarizes qualitative data collection techniques and their various forms.

Forms	Types	Definitions
Observation	Field notes and drawings	Unstructured data and pictures taken during observation by the researcher
Documents	Notes about documents or scanned documents	Private (e.g., from a meeting) or public (e.g. journals) records available to researcher
Interviews	Transcription of structured, semi-structured or open ended interviews	Unstructured data obtained from transcribing the interview
Audiovisual	Sounds, pictures, photographic objects	Audiovisual data consisting of sounds recoreded by the reseracher or someone else

Table 18: Forms of Qualitative Data Collection
Source: Author's own illustration, adapted from Creswell (2013) and Saunders et al. (2012)

Especially the use of semi-structured expert interviews is well-suited for the in-depth and systematic analysis of experiential reports (Bryman and Bell, 2015; Misoch, 2019). Meuser (2009) describes the expert interview as an instrument of data collection that is related to a specific mode of knowledge - expert knowledge. In the context of scientific work, an expert is defined as a person who owns exclusive information about the research area in question, and thus possesses a knowledge advantage (Meuser, 2009), so that well-founded information can be provided (Bogner et al., 2005). To establish a pool of suitable organizations and candidates, the most commonly used sample technique in applied research is commonly used – purposive sampling (Leedy and Ormrod, 2016; Tongco, 2007; Miles and Huberman, 1994). Although Patton (2002) outlined 16 types of purposive sampling techniques, the most commonly predetermined criteria a possible interviewee should have are noted in advance so that people are chosen which are "typical" or represent diverse perspectives on a particular research objective (Guest et al., 2006; Tongco, 2007; Ritchie et al., 2014). A specific sampling design or characteristics of participants are commonly not used (Bernard, 2006), so the researcher decides which individuals are most experienced and knowledgeable to accomplish the set research objectives (Etikan, 2017). When performing semi-structured interviews, the use of an interview questionnaire with clearly delineated topics is intended to give a uniform structure and increase the comparability of the results (Misoch, 2019). To structure the guide, individual sub-aspects of the theory are deductively divided into categories and then key terms were defined to answer the research question (Gläser and Laudel, 2010). This enhances the flow of conversation and improves data comparability (Misoch, 2019). Nevertheless, the semi-structured form allows additional questions and unanticipated themes to emerge that are relevant to the topic to be asked without running the risk of the interview getting lost in extraneous topics (Bhattacharya, 2017; Braun and Clarke, 2013). Furthermore, the chosen interview method allows individual contextual circumstances and methodological constraints can be reduced (Strübing, 2018).

"*Qualitative research is often criticized as biased, small-scale, anecdotal, and/or lacking rigor; however, when it is carried out properly, it is unbiased, in-depth, valid, reliable, credible, and rigorous*" (Anderson, 2010, p. 2). Therefore, criticism of qualitative research is mainly based on the high level of subjectivity, poorly-written data analysis process, and small sample sizes, which generate low reliability of the findings (Eisenhardt et al., 2016; Thomson, 2011a). Furthermore, the analysis and interpretation of data take a considerable amount of time and the smaller sample size raises issues regarding generalizability to the whole population of the research (Flick, 2015; Thomson, 2011a; Pratt et al., 2020). Furthermore, qualitative researchers view the social world as dynamic rather than static, limiting the findings to the particular group of people under investigation (Daniel, 2016; Johnson and Christensen, 2014). The absence of numerical data limits the simplification of findings and reduces the replicability of the study. In addition, explanations and analysis are based on the researcher's interpretations, which is seen as further limitation to qualitative research (Daniel, 2016; De Vaus, 2014). Furthermore, qualitative interviews tend to generate biased results, as participants are more likely to respond in a morally and socially correct way (Bergen and Labonté, 2020). Several authors highlighted the pre-testing of the interview guide to ensure an understandable questioning and interview process (Kallio et al., 2016; Majid et al., 2017; Saunders et al., 2012; Crick, 2021) to refine measures before confirmatory testing (Hair et al., 2010). Several authors claimed that the weaknesses of qualitative research are diminished by discussing aspects of validity and reliability, which are further elaborated in Chapter 4.5.

The concept of saturation and information power needs to be addressed to justify the sample size in qualitative research (Malterud et al., 2016; Sim et al., 2018). To achieve data saturation, research states different opinions regarding the number of interview participants and greatly differs depending on the type of study (Saunders et al., 2018). Glaser and Strauss (2010, p. 61) define saturation in these terms: "*The criterion for judging when to stop sampling the different groups pertinent to a category is the category's theoretical saturation. Saturation means that no additional data are being found whereby the sociologist can develop properties of the category. As he sees similar instances over and over again, the researcher becomes empirically confident that a category is saturated.*" While some argue that up to thirty interviewees are necessary (Creswell and Poth, 2018; Marshall et al., 2013; Thomson, 2011b), others recommend six to eight (Kuzel, 1999) or twelve (Guest et al., 2006) interviews to reach saturation. A recent SLR conducted by Hennink and Kaiser (2022) found that within qualitative research saturation is reached through nine to seventeen interviews or four to eight focus group discussions. Nevertheless, saturation is generally influenced by specific parameters such as the nature of the study population or study goal (Hennink and Kaiser, 2022). The theory of information power argues that attention is shifted from the amount of input to the content of input, assuming that the more relevant information the interviewees disclose, the fewer are needed (Malterud et al., 2016). Furthermore, within the findings of the study of Thomson (2011) analyzing one hundred papers using qualitative interviews as a data collection technique, it is concluded that the more expertise the researcher has in the respective research field, the fewer interviews are needed to generate a valid result.

4.3.1.2. Quantitative Research

'Quantitative' is often used as a synonym for data generation using standardized numerical data such as questionnaires, surveys, and data analysis procedures such as graphs or using a range of statistical techniques. The underlying tenets are a philosophical belief that our world is uniform and stable and that facts and feelings can be separated (Fraenkel et al., 2012). Quantitative research is structured with predetermined variables, hypotheses, and design (Creswell, 2013). Due to their standardized measures, quantitative research tends to have large samples and generalizable data (Hair et al., 2024; Mertler, 2022) and is generally used to test theory with a series of research hypotheses (Combs, 2010; Crick, 2021). Due to the fact that the researcher follows typically hypotheses-led guidelines and objectives, the replicability of the experiment is another benefit of quantitative research (Lichtman, 2014). Imperatively, quantitative research can be characterized as scientific in nature (Daniel, 2016). Whereas in qualitative research the researcher is generally part of the research, in quantitative research, the scientist is seen as independent from the research respondents (Basias and Pollalis, 2018; Creswell, 2013). Quantitative research is associated with survey or experimental research strategies using questionnaires, structured interviews, or observation (Saunders et al., 2012). Furthermore, existing datasets may be used to perform quantitative statistical research (Creswell, 2013). Descriptive statistics (averages, percentages, means, standard deviations) and inferential tests (e.g., correlations, regressions) are used to analyze the data. Therefore, the randomly selected larger sample size likely causes findings to be generalized to a whole population or sub-population (Rahman, 2016).

Beyond the stated advantages, some limitations are apparent. Critics of quantitative methods argue that this type of research tends to have little or no contact with the social phenomenon studied (Blaikie, 2007; Denzin and Lincoln, 2013). As opposed to qualitative research, in quantitative research, it is difficult to get in-depth knowledge of the phenomenon studied (Johnson and Christensen, 2014). As a result of the predetermined working process, imaginative or creative thinking is generally not encouraged (Daniel, 2016). Furthermore, the quantitative research approach has a tendency, caused by the variable testing at a specific moment in time, of taking a snapshot of a phenomenon without evidence of more profound insights (Hammersley, 2007).

4.3.1.3. Mixed research

In the past, management research either adopted a qualitative or a quantitative approach. Whereas the latter was predominantly used since the twentieth century, qualitative research with a focus on interpretive and narrative investigations gathered via observations and communication gained interest in the mid to late twentieth century (Creswell, 2013; Jogulu and Pansiri, 2011). Being the third paradigm, mixed research or multimethod research is known to integrate thematic and statistical data to expand and create divergent views of findings as well as a more sophisticated research design (Jack and Raturi, 2006; Saunders et al., 2012). *"Having an inductive-deductive cycle enables researchers to equally undertake theory generation and hypothesis testing in a single study without compromising one for the other"* (Jogulu and Pansiri, 2011, p. 688). Therefore, the triangulation of research approaches, thus reducing the dominance of one research technique, is producing an outcome of high standing (Jogulu and Pansiri, 2011) leading to thicker and richer data and uncovering contradictions as well as increasing validity and rigor (Jick, 1979; Johnson and Onwuegbuzie, 2004; Lo et al., 2020). What is more, the obtained results, as well as correlations with mixed research, are commonly not obtained when using only one research paradigm (Johnson and Christensen, 2014). Furthermore, the aforementioned criticism of research approaches is reduced, providing the rationale for conducting mixed methods research (Lieber and Weisner, 2010). Although the call for using mixed methods studies had been too old (Campbell and Fiske, 1959), studies applying it in business research are still rare (Hohenthal, 2007; Lo et al., 2020). Creswell (2013) identified three basic methods to conduct mixed methods: the convergent parallel design (1), the exploratory sequential design (2) and the explanatory sequential design (3). Within the convergent parallel design, a simultaneous collection of both qualitative and quantitative data is anticipated where both data have equal priority (Bryman and Bell, 2015). The second design entails collecting qualitative research followed by a quantitative phase. The third design involves gathering quantitative data followed by a qualitative phase to elaborate on the findings of the first phase (Creswell, 2013).

4.3.2. Qualitative Data Analysis Techniques

When it comes to qualitative data analysis, several authors emphasize justifying the 'how' and 'why' to make the findings as transparent as possible (Gioia et al., 2013; Shah and Corley, 2006; Sinkovics et al., 2008). What is more, Berg and Lune (2012, p. 4) highlight that "*Qualitative research is a long hard road, with elusive data on one side and stringent requirements for analysis on the other*". Qualitative researchers have created many data analysis techniques, whereas a central criterion is the code-led approach, meaning to organize collected raw data into themes (Crick, 2021; Jonsen et al., 2018). This can be done either manually or in electronic forms with data analysis software (Goulding, 2005). Whereas the latter can save time, manual coding needs a robust, systematic system and is better for intricate data details (Rettie et al., 2008). Two major techniques are predominantly used within the research community, deductively or inductively generated codes (Azungah, 2018). Whereas the latter is a recursive process based on the generated material (Curry et al., 2009), deductive codes are developed in advance before the research commences and often act as a starting point for data screening (Azungah, 2018; Saunders et al., 2012). Mixed methods are also possible where codes are derived from theory, and others are drawn from the collected data material (Mayring, 2014). Data analysis techniques that commonly meet the scientific requirements in terms of transparency, objectivity, and scientific quality criteria are, on the one hand, *Grounded Theory* and, on the other, *qualitative content analysis* (Nowell et al., 2017). Both concepts will be further elaborated in the upcoming section.

4.3.2.1. Grounded Theory

Grounded Theory was developed in 1967 by Glaser and Strauss, follows an inductive, constructivist approach, and is suited solely for qualitative research (Khan, 2014; Strübing, 2014). The aim is to discover a theory grounded in the data produced and to formulate a theory based on interrelated concepts, i.e., a network of concepts rather than empirical testing of theory (Glaser and Strauss, 2010). The basic principle is to enter the field of research as soon as it has been identified. However, a common misconception within Grounded Theory is that the field is entered ignoring any literature theory, rather it is an "*iterative, inductive and interactional process of data collection, simultaneous analysis, and emergent interpretation*" (Goulding, 2005, p. 296). Therefore, the researcher should be directed to relevant literature revealing data-grounded concepts (Mey and Mruck, 2010). Grounded Theory proposes a multi-stage evaluation procedure of the collected data, which Glaser and Strauss differentiate into open, axial, and selective coding. The three stages are not strictly delimited from each other, nor are they to be understood in a fixed sequence (Corbin and Strauss, 1990). *Open coding* refers to breaking open the data by generating initial codes that capture main ideas and preliminary concepts (Strübing, 2014). This stage involves a line-by-line analysis, marking of recurring terms, grouping of terms by characteristics, and forming of keywords to guide the researcher further in theory and explanatory concepts. For analyzing and abstracting information, the "constant comparison" method, i.e., the constant moving back and forth of theory and data, ensures that information is compared and consistent (Glaser and Strauss, 2010). On the other hand, with *axial coding,* interrelationships within the data and delineating core categories are formed (Glaser and Strauss, 2010). Each category contributes to explaining a social phenomenon, and coding lines need to be traced back to the data. The significance of these core categories is evaluated with *selective coding* by systematically relating the core categories to other core categories and sub-categories. Finally, conclusions are drawn, and answers to the central research questions and recommendations for further research are commonly provided as a final step (Strübing, 2014). Nevertheless, data collection an analysis always '*blur and intertwine continually*' (Glaser and Strauss, 1978, p. 43).

Furthermore, sampling is different from most other research methodologies. Whereas most sampling is purposive, i.e., defined before data collection, in Grounded Theory, sampling is started by talking to informants who are most able to provide early information (Bryant and Charmaz, 2007; Goulding, 2005). Saturation is reached when no additional information is found in the data. Whereas any form of data collection technique is possible within the Grounded Theory process (Glaser and Strauss, 2010), conducting semi-structured in-depth interviews and focus groups are most appropriate (Khan, 2014). While Grounded Theory is often used within a qualitative research setting, it is also an appropriate methodology for conducting the literature review process. There, it is essential to research on academic theory early in the research stage, to be assured that the project is not duplicating existing work or tangent irrelevant areas (Dunne, 2011). Using grounded theory within the literature process enables the researcher to reflect on the academic literature's values as well as limitations.

4.3.2.2. Qualitative Content Analysis

An alternative method of decoding qualitative data is the qualitative content analysis based on the concept of Mayring (2014). Information is systematically extracted in order to increase comparability and reliability and is analyzed as written communication (Mayring, 2014). This analysis technique is about to summarize the conducted data in meaningful categories, which in turn evolve into an organized theory system. Therefore, the most significant feature of content analysis is the rule-governed approach – by forming categories either deductively or inductively. The latter is also acknowledged as a bottom-up way and involves establishing themes/categories deriving from the data, ignoring themes that might have developed in previous literature. On the other hand, deductive category-building is known as top-down approach and instead categories are directed by the researchers prior knowledge in the research field of investigation (Christou, 2022; Mayring, 2010). Using both approaches with a combination of prior knowledge as well as open-mindedness to new data is as well appropriate. A category is characterized as an identifier to assign text passages accordingly (Kuckartz and Rädiker, 2022). Subsequently, the data is summarized for interpretation by attempting to theorize the significance of the identified patterns (Christou, 2022). The conducted analysis technique of this dissertation is presented in Figure 14. This process model ensures that the content analysis is systematic and comprehensible for others, ensuring reliability.

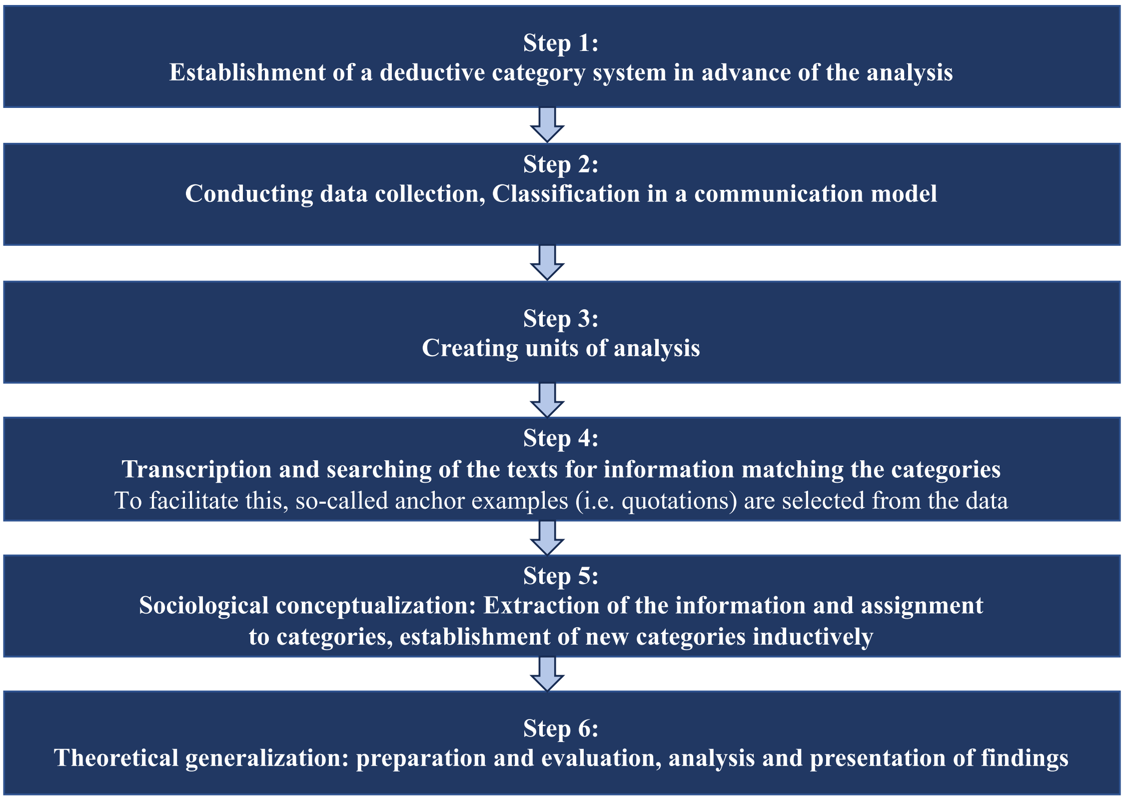


Figure 14: Research Process Qualitative Content Analysis
Source: Author's own illustration, adapted from Mayring (2014), Gläser and Laudel (2010), Meuser and Nagel (2009), and Kuckartz and Rädiker (2022)

Before starting data collection, a deductively established category system derived from the initial literature review should be established (Step 1) (Meuser, 2009). The development of categories, along with the clear definition of their conceptual boundaries, presents a complex and methodologically challenging task (Krippendorff, 2004; Kuckartz and Rädiker, 2022). Commonly, a category is understood as an identifier or something significant to which a text passage may be assigned (Mayring, 2014). Furthermore, it is emphasized by Kuckartz and Rädiker (2022) that a prerequisite of functional category is selectivity i.e., that the text content is assigned to only one category. What is said or written within the data collection process is classified in a communication model and contains information about the text producer (i.e., experiences, attitudes, feelings) deriving from the asked questions (Step 2). The data is then subsequently derived into units of analysis (Step 3) by transcription and searching of text for category matching using anchor examples (i.e., anchor examples) (Step 4). New categories may be added inductively if the text passages do not fit into the preset categories (Step 5). In this way, categories are constantly developed and reworked and may be continuously adapted according to the requirements of the present study and its individual circumstances (Mayring, 2014). The final step consists of the theoretical generalization and presentation of results (Step 6).

4.3.2.3. Comparison

When comparing the Grounded Theory and the content analysis procedure, scholars underline that both overlap in certain stages and approaches (Flick, 2015; Silverman, 2011). For example, being inductive by nature, a theory emerges iteratively when decoding with Grounded Theory. However, in qualitative content analysis, categories are also formed deductively and may be added inductively during the research process. Whereas it is argued that qualitative content analysis often involves a more structured approach to analyzing data. Therefore, flexibility and openness to unexpected findings are ensured in both concepts. During the analysis process, it is often described that the breaking down of the material through open coding in Grounded Theory is similar to the stages in content analysis (Silverman, 2011).

4.3.3. Quantitative Data Analysis Techniques

Quantitative data analysis is a systematic process of collecting and evaluating a large data set (Creswell, 2013). Mechanisms and techniques in quantitative data analysis are predominantly done using the assistance of computer analysis software such as Microsoft SPSS (Cowles, 2005). Commencing the step of data collection, the goal is to organize and visualize data in a meaningful form. Generally speaking, two types of data analysis techniques can be differentiated – descriptive and inferential statistics (Stapor, 2020).

4.3.3.1. Descriptive Statistics

Descriptive statistics summarizes an observation by converting it into numerical figures. It is, therefore, describing the characteristics and ordering the dataset in a particular manner without consideration of further generalization beyond the data (Cowles, 2005). Dominant measures in descriptive statistics are central tendency and measures of dispersion (Stapor, 2020). Central tendency analysis determines the most represented value in comparison to a set of data. Whereas mean is the average of values, medium is the middle value in the data set, and mode is the value that most frequently occurs (Taherdoost, 2020). Measures of dispersion define the way of spreading the values around the central tendency, tapering off at the tail ends. For example, the range is the amount of spread between the highest and the lowest value (Saunders et al., 2012). Standard deviation (SD) indicates how dispersed a dataset is relative to its mean. Whereas a low standard deviation indicates a value close to the mean, a high standard deviation shows that the values within a data set are spread out over a wide range (Plaue, 2023; Saunders et al., 2012). The variance is the square of the SD and illustrates the concentration of values around the mean value, underlining the connection between the two data sets. Another form of dispersion is the simple or bivariate correlation. A correlation can be drawn using the data set mean values and standard deviations (Bhattacherjee, 2012).

Data presentation is commonly done using graphical tools such as charts, tables, histograms or graphs (Boslaugh and Watters, 2008). These visual aids help to identify patterns and trends (Saunders et al., 2012). A graph can be characterized as a diagram that displays a relationship between two or more quantities (Creswell, 2013). Once the data is organized and visually presented, meaningful conclusions can be drawn by the researcher (Newbold et al., 2013). Descriptive statistics often serve as a prerequisite or initial step of analysis and is commonly done before more complex inferential and predictive analyses are made (Evans and Rosenthal, 2004).

4.3.3.2. Inferential Statistics

Inferential statistics is about generalizing from the dataset to the larger population, i.e., making predictions beyond the data available by making probabilistic statements (Boslaugh and Watters, 2008; Bryman and Bell, 2015). Therefore, roots of inferential statistics trace back to probability theory and logic reasoning (Hald, 1990; Welsh, 1996). Probability testing is facilitated to mitigate the effects of uncertainty and reduce variations in the data. Logic reasoning enables sensible decisions and accurate predictions based on the collected data (Bandyopadhyay and Forster, 2011). In this light, hypothesis testing is appropriate for identifying relationships between variables in the population data.

An assumption is made regarding the null hypothesis (H_0), which states that there is no difference between the populations. If sufficient evidence is found, the null hypothesis is rejected, which suggests that the data points are not independent (Saunders et al., 2012). Errors can occur when producing inferential statistics.

According to Boslaugh and Watters (2008) four consecutive steps are necessary for hypothesis testing:

1. Develop a hypothesis which is possible to be tested in a mathematical way
2. Name the null and alternative hypotheses
3. Decide for the appropriate statistical test and perform calculations
4. Describe decision and results.

To decide whether there is enough evidence to reject the null hypothesis, a significance level (α) must be set. For statistical testing, 5% significance level has been challenged numerous times, but remains common in academic research (Boslaugh and Watters, 2008). The next step is then to calculate the associated probability value ("*p-value*"), i.e., measuring the probability of a statistic equal to or more extreme than the hypothesis test (e.g., t-test, chi-square test). Accordingly, a result with $p \leq .05$ is considered significant, and the alternative hypothesis will be accepted (Andrade, 2019; Saunders et al., 2012). In the research literature $p \leq .01$ is often considered highly significant, indicating stronger evidence against the null hypothesis (Sawyer and Peter, 1983). With regards to errors in quantitative research, researchers refer to a Type I error when the null hypothesis is wrongly rejected. Type II errors involve the opposite, i.e., accepting the null hypothesis when it is actually not true. In academic research, assertions of truth that do not align with reality are considered more serious (Blumberg et al., 2008; Boslaugh and Watters, 2008). Therefore, setting an appropriate significance level reduces the likelihood of making a Type I error (Saunders et al., 2012). Before testing commences, the concept of standard error and confidence intervals must be discussed to increase the validity of the results (Boslaugh and Watters, 2008). When a measurement error exists, the probable error rate should be reported. The standard error is, therefore, an estimate of the variation of error in the research data and is commonly calculated by standard deviation divided by the square root of sample size. Thus, when the sample size increases, i.e., the sample size gets closer to the true size of the population, reliability increases, and the standard error decreases (Boslaugh and Watters, 2008). To execute inferential testing, the concept of different variables must be explained. A dependent variable is defined as a variable whose observed value is determined by one or more independent variables (Flick, 2015).

Therefore, dependent variables are characterized by the study's outcome; independent variables are presumed to influence the value of the dependent variables. A third category, called control variables, is implemented to increase explanatory power and avoid the multicollinearity of variables. These are not of primary interest for the research focus but are perceived as researchable (Boslaugh and Watters, 2008).

There are two main groups of statistical tests – parametric and non-parametric. Parametric statistics are used with numerical data and are considered more powerful (Saunders et al., 2012). Nevertheless, the data needs to possess several characteristics to generate valid results. First, the data must be normally distributed, i.e., clustered around the arithmetic mean and falling off evenly on both sides (Boslaugh and Watters, 2008). Based on the validity of the central limit theorem, Bortz and Schuster (2016) are highlighting that this assumption is given with a group sample size above 30 data points. Second, a homogeneity of variances, i.e., each group needs to possess approximately equal variances, is necessary (Rasch et al., 2014; Sheskin, 2011). Third, the data must be independently and randomly sampled from the population (Blumberg et al., 2008). Fourth, no extreme outliers exist that could adversely affect the test result (Zimmerman, 1994). On the other hand, non-parametric tests commonly do not fulfill the above-written characteristics, i.e., make no assumptions about the data distribution and base their calculations on the median (Blumberg et al., 2008; Sheskin, 2011). Common varieties of inferential tests are comparison tests, correlation, and regression analysis.

Comparison Tests

These tests compare means of groups to assess group differences in outcomes. A one-sample t-test is used when one sample is compared to the population mean (Witte and Witte, 2017). The two-sample or independent t-test compares two independent or unrelated data group means (Boslaugh and Watters, 2008). Conversely, paired t-tests are used to compare the means of two related samples, typically applied when measurements are taken from the same group at two different points in time—for example, before and after an intervention (Newbold et al., 2013). When the sample is skewed, the Mann-Whitney test is the non-parametric equivalent of the paired t-test (Saunders et al., 2012). When a numerical variable is divided into more than three independent groups the analysis of variance (ANOVA) is chosen. ANOVA calculates the ratio of the between-group variance to assess whether there are statistically significant differences between the groups (Saunders et al., 2012). The statistical results are equal to multiple t-tests. The Chi-squared test is a standard non-parametric test that compares expected frequencies, i.e., whether the data in the table could occur by chance alone (Saunders et al., 2012). In other words, if the variables are unrelated, the marginal distribution only affects the joint frequencies (Boslaugh and Watters, 2008).

Correlation Tests

In correlation testing, the relationship or statistical association between variables without assuming causation is assessed (Boslaugh and Watters, 2008). Researchers often use scatter plots to explore associations graphically by taking an explanatory variable (usually the x-axis) plotted against a response variable (usually the y-axis). The data points are then inserted, and a sense of the overall pattern emerges. This pattern may be influenced by outliers or random errors, which must be evaluated. The association form can be either linear or nonlinear (Boslaugh and Watters, 2008). While scatterplots are an appropriate visual tool for examining relationships, single quantitative measures test correlation more concisely. The most commonly used parametric correlation test to measure the strength and direction of two variables is the correlation coefficient *Pearson's r* (Rasch et al., 2014). In other words, the more the variables are related, i.e., similar to a straight line in a scatter plot, the more correlated the variables are (Boslaugh and Watters, 2008). The *effect strength* between two variables ranges between -1 (perfect negative correlation) to 1 (perfect positive correlation) (Field, 2007; Saunders et al., 2012). With a correlation value of 0, the two variables can be assumed to be independent (Boslaugh and Watters, 2008). A requirement for *Pearson's r* is a t-test of the correlation coefficient to obtain a corresponding p-value, i.e., whether the correlation coefficient is significant (Saunders et al., 2012). Several authors argue that Type I and Type II may be inflated when performing a *Pearson r* statistical test on non-normal data (Bishara and Hittner, 2015; Blair and Lawson, 1982). As a non-parametric correlation test, *Spearman's Rho* is more feasible with data with non-normal distribution (Bishara and Hittner, 2015). Both tests are usually performed with continuous variables. When one variable is dichotomously characterized, the point-biserial correlation (equivalent to *Pearson R*) or rank-biserial correlation (equivalent to *Spearman Rho*) is used (Cureton, 1956; Kornbrot, 2014).

Regression Tests

The cause-and-effect relationships between two variables (linear or bivariate regression) and multiple variables (multiple or multivariate regression) are assessed in regression analysis (Field, 2007). In linear regression, the goodness of fit of observed data to a theoretical model is measured. In other words, linear regression enables the characterization of data and the prediction of the values of dependent variables from independent ones (Boslaugh and Watters, 2008). Linear regression is based on the geometry of a straight line, representing the hypothesized linear relationship between two variables. Although the deviations from these lines are used to calculate the correlation coefficient, more importantly, along the straight line, a prediction for the dependent variables can be taken based on the values of the independent variable (Saunders et al., 2012). When the dependent variable is continuous, linear regression modeling is used; logistic regression is performed when the variable is binary or dichotomous (Hosmer et al., 2013). Regarding independent variables, categorial and continuous variables should be directly entered into regression analysis. For binary variables, dummy variables need to be coded with 0 (“no”) and 1 (“yes”) (Hosmer et al., 2013; Tripepi et al., 2011).

The following equation displays a simple linear regression model where *y* represents the dependent variable, and *x* is the independent variable. The term *u* represents the remaining factors other than *x* that influence *y*. Consequently, *x* has a linear effect on *y*, explained by the independent factors listed in β_1- $\beta_{...}$ and the intercept parameter or constant term β_o. All factors other than *x* are treated as unobserved in linear regression modeling. The aim of linear regression is to minimize the error term to find those parameters β_o and β_1 to minimize the error term *u* (Wooldridge, 2013). In other words, regression analysis minimizes residuals and in turn, produces the smallest possible standard errors.

$$y = \beta_o + \beta_1 x + \beta_2 x + \beta_3 x + \beta_{...} x + u$$

Similar to correlation analysis, certain assumptions must be fulfilled when performing regression analysis. First, the chosen sample must be representative of the population, and a linear relationship between independent and dependent variables is assumed. Second, multivariate normality is generally needed. However, testing can still be performed in large sample sizes (commonly above 30 data points) when the normality assumption is violated (Bortz and Schuster, 2016; Li et al., 2012). Third, the multicollinearity needs to be tested as a high correlation between independent variables undermines the statistical significance of an independent variable and consequently impairs the correct interpretation of results (Allen, 1997). Fourth, outliers must be minimized so that the model is not influenced by anomalous data points (Wooldridge, 2013).

Time Series Analysis

Variables changing over time, as well as longitudinal research, can be analyzed using time series analysis. The term is defined as ‘*as a set of quantitative observations arranged in a chronological order’* (Kirchgässner and Wolters, 2007, p. 1). The aim is to summarize data and make predictions using regular intervals and a large number of data points. Simple analysis involves trend analysis or moving averages. More sophisticated models, such as regression analysis, can complement time series analysis to test the relationship between different variables or sets of variables (Bhattacherjee, 2012). In essence, time series analysis delves into the intricate dynamics of temporal data.

4.4. Research Design and Method Selection

Generally speaking, the research design refers to the guideline that links the steps of the methods of data collection i.e., describing the practical procedures to reach the aim of the study and answering the research questions (Saunders et al., 2012). The research design of this dissertation project is presented in Figure 15 and generally follows an explanatory sequential mixed methods design by conducting a qualitative phase followed by quantitative research (Creswell, 2013). The rationale for using this form of mixed method design is that an in-depth understanding of the phenomena is developed beforehand in a qualitative setting, followed by a validation with a quantitative data set. While studies related to the field predominantly conducted quantitative research to test environmental resource variables against hotel characteristics (Antonova et al., 2021; Bohdanowicz and Martinac, 2007; Priyadarsini et al., 2009), this dissertation aims to question the variables through an in-depth qualitative phase before conducting quantitative research. Additionally, the geographic focus on the German and Austrian hotel sector introduces a novel contribution to the literature, as this regional context is largely underrepresented in past research. Employing a mixed methods design thus not only enriches the understanding of the topic but also ensures methodological rigor by integrating the strengths of both qualitative exploration and quantitative validation. This approach allows for the development of more grounded, context-sensitive theories that would be difficult to achieve through a single methodological lens.

As indicated in Figure 15, the empirical research commences with an initial SLR (Phase 1) using grounded theory as a decoding data analysis technique. Relevant regulatory reporting standards, ESG certification schemes as well as environmental industry frameworks are assessed to determine relevance. Furthermore, the annual ESG reports of the largest European and international hotel companies are screened. Findings from academic and industry sources are blended to identify research gaps and form hypotheses to be tested. Then, a valid research methodology is created to match the aim and objectives of the research.

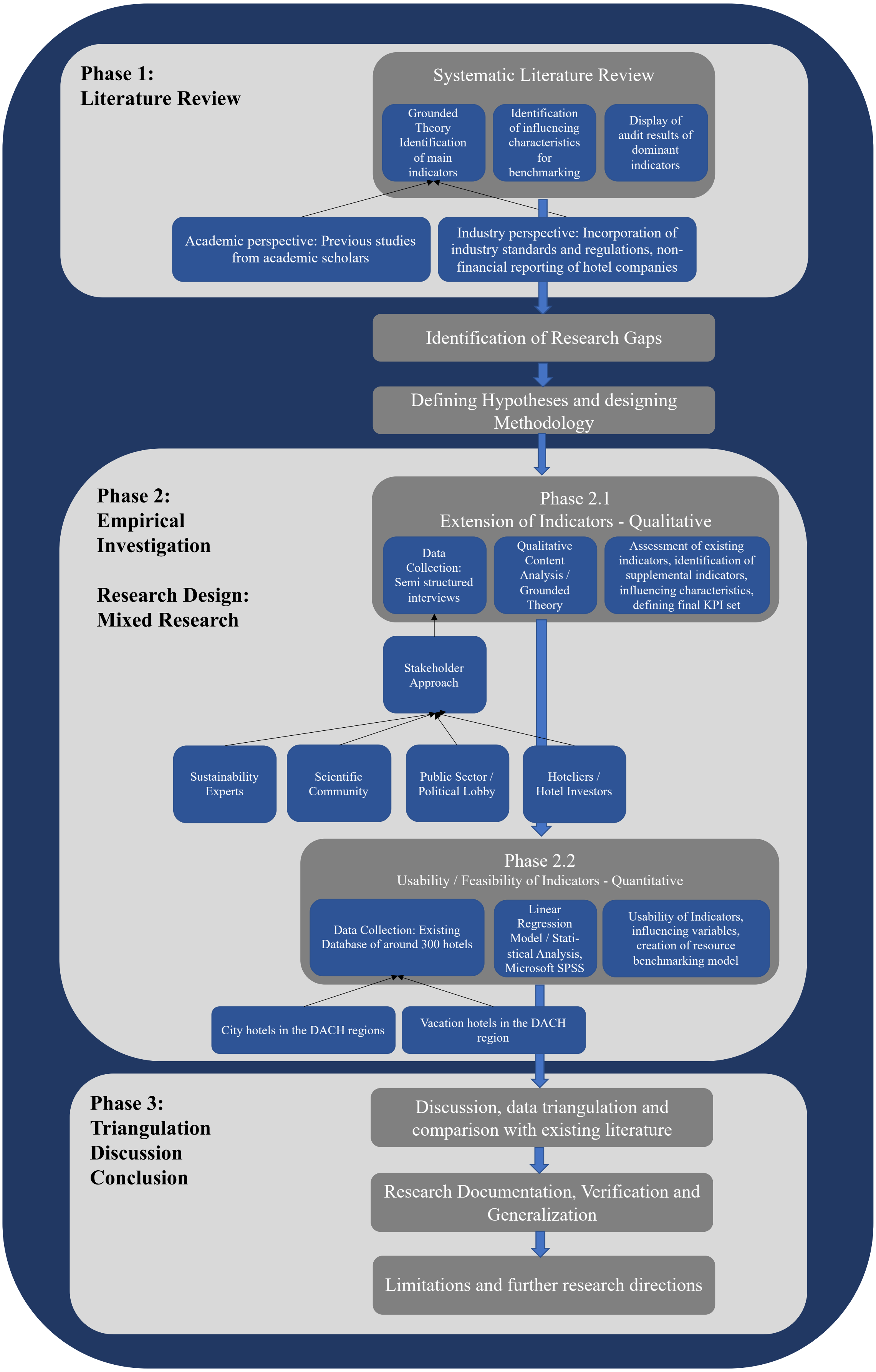


Figure 15: Research Design
Source: Author's own data

Using semi-structured interviews of different stakeholders (Phase 2.1), the findings will be extended and subsequently decoded using qualitative content analysis, according to Mayring (2014). Following the qualitative phase, the usability and feasibility of the defined KPI set, as well as influential factors, are tested on a quantitative data set (Phase 2.2) consisting of around 300 hotels. For the descriptive and inferential statistical analyses, the statistical software IBM SPSS® 29 is used. For the core hypothesis tests, the significance level is set at $\alpha = 5\%$, corresponding to the probability of error, i.e., the risk of making an incorrect assumption whether the null hypothesis is rejected and the alternative hypothesis is accepted (Creswell, 2013). This significance level is consistent with those used in other studies within the same research domain (Antonova et al., 2023; Mclennan et al., 2017). Regarding descriptive statistics, the values mean (*M*) and standard deviation (*SD*) are used for metric parameters. In skewed distributions, the alternative positional measure median (Md) is used, while for nominally scaled variables, the frequencies (*n*) and their proportion values (%) are determined. Bar and pie charts with corresponding error indicators (± 1 SD) are created to illustrate the distribution of metric parameters. Likewise, line diagrams for profile progressions and histograms for the distribution of measured values of individual items are the preferred form to display findings. Within the framework of inferential statistics, the appropriate inferential statistical methods are used according to the requirements regarding data level and distribution assumption. This involves correlation as well as multiple linear regression models to predict resource consumption and its influential characteristics ultimately. In Phase 3 of this dissertation project, the findings of the conducted phases are discussed, and comparisons with previous studies are made. As a last step, conclusions, limitations, and further possible research fields are investigated.

4.5. Assuring Objectivity, Reliability, and Validity

To legitimize the research design and ensure the trustworthiness of the findings, an assessment of objectivity, reliability, and validity must be done (Creswell, 2013). Whereas within quantitative research the dimensions are somewhat clear (Misoch, 2019), especially in qualitative research the role is blurred and researchers should be cautious about using terminology with quantitative connotations (Sinkovics et al., 2008). Objectivity refers to the independence of the test result from the researcher and is a logical prerequisite for reliability and validity matters (Creswell, 2013; Letherby et al., 2013). In qualitative research, objectivity is linked to reflexivity, where biases, assumptions, and perspectives are acknowledged to minimize their influence on the research process (Finlay, 2002). Thus, to minimize bias, the researcher continuously triangulated interviews with existing documents in order to cross-check and validate the evidence

(Azungah, 2018). Furthermore, peer debriefing is another possibility to increase reflexivity and objectivity (Denzin and Lincoln, 2011). The researcher engaged in discussions with peers and experts to critically evaluate the research process and findings, helping to mitigate subjective biases. Finally, scholars emphasize the thorough documentation of decisions, methodologies, and interpretations of the research process, allowing others to validate the objectivity of the study (Creswell, 2013). This was achieved by continuous documentation of the research steps via an extensive Excel database as well as the codebook of the qualitative interview process. In the quantitative phase, the SPSS database with all statistics, model calculations, and visual graphics is available upon request. The term validity is defined as '*the issue of whether or not an indicator (or set of indicators) that is devised to gauge a concept really measures that concept*' (Bryman and Bell, 2015, p. 170). In a qualitative setting, providing context-rich descriptions of research context, participants, and findings ensures high validity of results (Creswell and Miller, 2000). Furthermore, scholars often highlight a member-checking process where participants are integrated into the research process to review findings, ensuring that the study accurately represents their experiences (Morse, 2015). While discussions of findings were done bilaterally with interview participants, the results were discussed and validated during the annual conference of the university institute[17]. There, a panel of 120 experts from research and practice listened to a 20-minute presentation followed by a 20-minute Q&A session. In the quantitative phase, results were validated by statistics experts of the university as well as hotel experts to assess overall rigor. Practical validation was further attained with an oral presentation of the quantitative findings at the Real Estate User Group (REUG)[18] quarterly meeting of the university institute. Scientific validation is underlined with the various publications outlined in the preface of this dissertation.

According to Bryman and Bell (2015, p. 169) '*reliability refers to the consistency of a measure of a concept'*. In sum, reliable results are generated when the same outcome is generated when the same research project is repeated at a later time, i.e., only small disparities occur when the measure is reliable. Different scholars link reliability to using multiple data sources and triangulating the found data with existing knowledge (Morse et al., 2002). This was achieved by using a mixed research approach consisting of a

[17] 16th IFM congress, Technical University of Vienna held on 23rd and 24th November 2023
17th IFM congress, Technical University of Vienna held on 21st and 22nd November 2024, more information see https://www.tuwien.at/mwbw/im/ie/ifm/kongress/programm

[18] For more information about the Real Estate User Group see https://www.tuwien.at/en/mwbw/im/ie/ifm/reug-real-estate-user-group

qualitative and quantitative phase as well as a stakeholder approach within the interview phase to gain insights from different perspectives. Similar to objectivity matters discussed above, thorough documentation of research steps enabling others to replicate the research increases the reliability of the findings (Patton, 2015). Furthermore, it is highlighted that to attain high reliability of an academic study standardized procedures for data collection are necessary. Here, the interview process was standardized with a semi-structured questionnaire to allow some room for freedom but limited to certain boundaries. Furthermore, interview saturation was only achieved as adding new participants did not acquire more information. In addition, data analysis was done using Grounded Theory as well as qualitative content analysis to ensure consistency of findings. In the case of the quantitative study, variations are expected to be minor as objectives as well as geographical zoning are clearly set. As indicated in other academic studies (Antonova et al., 2023), multicollinearity between variables might lead to a biased result in the estimation of coefficients. Hence, to counteract this possible problem, the variance inflation factor (VIF) is assessed.

4.6. Discussion and Conclusion Methodology

To conclude this section, key markers for quality in research are discussed. Tracy (2010, p. 837) identified a "*worthy topic, rich rigor, sincerity, credibility, resonance, significant contribution, ethics, and meaningful coherence"* as the main cornerstones for quality in research. First and foremost, the research subject is worthwhile and relevant due to the ever-increasing topic of sustainability and the challenges associated with it. Embedded in an explanatory sequential mixed methods research design, empirical work is executed in a stringent, highly transparent research flow. Furthermore, the research comprises sufficient theoretical structures outlined in a SLR analyzing close to 1,600 academic papers as well as analyzing current environmental reporting practices and legislative fundamentals. Empirical work commences with in-depth semi-structured qualitative interviews to gain in-depth knowledge of the German and Austrian hotel industry. In addition, analyzing the third-largest quantitative data set in energy and water resource benchmarking of the hotel industry further increases knowledge around the topic. Therefore, a broad resonance and substantial impact for academics and industry professionals alike is generated. Sincerity and reliability are also guaranteed through an accurate and transparent research process. Ethical concerns are thoroughly considered to ensure integrity, complete documentation of research steps, and transparent disclosure of conflicts of interest. Meaningful coherence is achieved by a logical and cohesive connection between research objectives, methods, findings, and conclusions, leading to a comprehensive understanding of the outlined research topic.

5. Qualitative Research Stage

This chapter outlines the qualitative research process, detailing the interview process and key findings from the qualitative phase of this study. The core statements from the interviews are systematically categorized and assigned to relevant codes. The collected data is then analyzed through comparison and contrast to highlight different stakeholder perspectives. Furthermore, the findings are contextualized by aligning them with insights from the previously conducted literature review (Chapter 2) and existing initiatives (Chapter 3).

5.1. Qualitative Research Process

The semi-structured interview guide illustrated in Appendix B serves as a framework for structured discussions on environmental sustainability in the hotel industry. It opens with general questions about the interviewee's role, experience, and engagement with sustainability. Next, a concise research project explanation provides context on the study's focus. The environmental practices section explores existing sustainability measurements and awareness of intensity indicators. Then, the following section delves deeper into defining valid input and reference variables, units of measurement, and time frames for tracking EGWW consumption. Interviewees are asked about clustering methods to establish benchmark values, considering factors such as hotel classification, occupancy, location, and operational characteristics.

The discussion concludes with identifying the most relevant intensity indicators and any additional missing insights to the research field. Before the beginning of data collection, the interview guide was pre-tested by two test persons (one academic and one industry expert) through a qualitative judgment to assess the overall comprehensibility, understandability, and structural set-up of the interview guide to meet the research objectives. Following the conduction of the interview, the audio recordings were transcribed using AI-based software, focusing on easy readability as well as smoothing out dialects and punctuations (Kuckartz and Rädiker, 2022). Furthermore, all data was anonymized to prevent conclusions relating to company names or personal information. Where necessary, quotations from the interview transcripts are translated from the original language, German, to English to facilitate easy reading and comprehensibility. Where required, the original German quote is illustrated as a footnote. The transcription is made available to reviewers as a PDF file and is included in Appendix C.

5.1.1. Selection of Participants

As previously discussed in Chapter 4.3.1.1, purposive sampling is employed to identify potential interview participants. When selecting the appropriate interview partners, care was taken to cover the heterogeneity of the topic. The experts were selected through the author's existing network and an extensive internet search using keywords similar to the SLR (see Chapter 2.1). The potential interviewees were contacted by phone or mail. To be eligible for being an interviewee, several criteria had to be met. First, the interviewees must be based within Central Europe to cover knowledge within the anticipated geographical area of the German and Austrian hotel industry. Second, they needed to be professionally active in the field of sustainability related to the hotel industry. Finally, an industry experience of 10 years as a minimum and a position within the upper management level was deemed necessary to be eligible. During the data collection process of this study, the researcher evaluated the accrued findings on an ongoing process and iteratively decided the amount of input further needed to answer the research questions (Sim et al., 2018). Given the narrowly defined research focus and the findings outlined in the data saturation section, a total of 16 interviews were conducted, at which point the researcher determined that the information gathered was sufficiently rich for the scope of the study.

To enhance the analytical depth while avoiding excessive data fragmentation, participants were categorized into four distinct stakeholder groups. This approach facilitates a more comprehensive understanding of the research topic by capturing diverse perspectives aligned with the study's objectives. The first group consists of sustainability experts (hereafter abbreviated SUE), primarily consultants in hotel advisory services and ESG advisory, who provide industry-specific insights. The second group includes *policymakers and regulatory entities* (hereafter abbreviated PO/L) responsible for shaping the legislative framework for non-financial disclosures, such as the CSRD or ESRS, and their national equivalents. The third group comprises *hotel operators and investors* (hereafter abbreviated HO/I), selected based on their sustainability track record and the number of properties under management, ensuring firsthand insights into current industry practices. Lastly, the fourth group represents the academic and *scientific community* (hereafter abbreviated SCC), consisting of scholars and researchers specializing in environmental sustainability within the tourism and hotel sector. By integrating perspectives from both practitioners and academics, the study achieves a balanced and comprehensive understanding of sustainability practices in the hospitality industry. During data collection, all participants were presented with the same set of pre-defined questions; however, the depth and scope of their responses varied considerably, reflecting differences in professional roles and subject-matter expertise. The interviews were recorded and subsequently transcribed according to the decoding scheme of Mayring (2014) for further analysis. A consent form relating to General Data Protection Regulation (GDPR) was sent and signed prior to each interview, consisting of a brief description of the study, the aim of the research as well as the confidentiality statement (see Appendix A).

5.1.2. Data Analysis and Coding

As outlined in Chapter 4.4, a sequential approach is adopted to analyze the qualitative data. Initially, a deductive approach is applied by forming categories from the codes from the existing literature aided by the research aims and questions. It is assumed that core concepts in the data are based on the common body of knowledge around the research field (Azungah, 2018; Thomas, 2006). Subsequently, missing categories are derived inductively during data collection (Mayring, 2014), to gain a holistic understanding of what has been said and that important codes are captured (Charmaz, 2014).

Core Categories Qualitative Phase			
Category / Sub-category	**Category Name**	**Category / Sub-category**	**Category Name**
C 1	**Environmental Practices**	**C 4**	**Waste**
SC 1.1.	What needs to be measured	SC 4.1.	General
SC 1.2.	Development of KPIs	SC 4.2.	Input variables
SC 1.3.	Standardisation Considerations	SC 4.3.	Reference unit
SC 1.4.	Measuring Methods / Technology Considerations	SC 4.4.	Unit for measurement
		SC 4.5.	Reporting Frequency
C 2	**Energy**	**C 5**	**GHG emissions**
SC 2.1.	General	SC 5.1.	General
SC 2.2.	Input variables	SC 5.2.	Current Practices
SC 2.3.	Reference unit	SC 5.3.	Reference unit
SC 2.4.	Unit for measurement	SC 5.4.	Unit for measurement
SC 2.5.	Reporting Frequency	SC 5.5.	Reporting Frequency
C 3	**Water**	**C 6**	**Influencing Factors / Clustering**
SC 3.1.	General	SC 6.1.	General about clustering of ESG data
SC 3.2.	Input variables	SC 6.2.	Physical factors
SC 3.3.	Reference unit	SC 6.3.	Operational factors
SC 3.4.	Unit for measurement	SC 6.4.	Outsourced departments
SC 3.5.	Reporting Frequency	SC 6.5.	Other factors

Table 19: Core Categories Qualitative Analysis
Source: Author's own data

Due to the interviews' heterogeneity, different perspectives are considered in the course of the analysis and aspects are also discussed on which not all interviewees have commented. This thorough back-and-forth analysis is the key reason for manually coding the entire workbook. The final coding matrix (see Table 19) outlines six core categories for the qualitative phase. Each category, Environmental Practices, Energy, Water, Waste, GHG Emissions, and Influencing Factors/Clustering, is divided into subcategories covering measurement needs, input variables, reference units, units of measurement, and reporting frequency. The Influencing Factors/Clustering category adds variables like physical and operational factors. The underlying Excel-based coding book is illustrated in Appendix D.

To conclude, as outlined in Figure 16, the study follows a structured three-step approach to qualitative content analysis. In Step 1, appropriate interview partners are identified, and stakeholder categories are formed deductively to ensure a structured and relevant selection process. Step 2 involves conducting semi-structured interviews with the four key stakeholder groups. This diverse selection allows for a holistic perspective on sustainability in the hospitality industry. Step 3 focuses on data analysis, where axial coding is applied to identify correlations, differences, and similarities between stakeholder perspectives. This process aligns with the principles of the Grounded Theory approach, particularly the axial coding phase (Strübing, 2014). As a result, qualitative content analysis in this study overlaps with the open and axial coding phases of Grounded Theory. The evaluation process reformulates key statements derived from the stakeholder interviews, ensuring a comprehensive synthesis of insights.

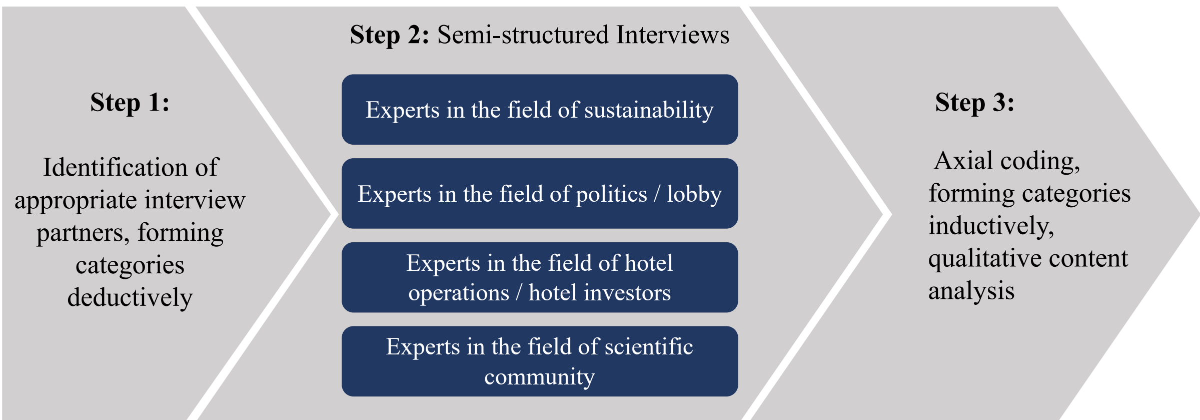


Figure 16: Methodological Process Qualitative Phase
Source: Author's own data

5.2. Results and Analysis

This section is dedicated to the results of the semi-structured interviews and follows the defined core categories derived from the Grounded Theory process of the literature review and deductively added categories from the interviews. The section order is derived from the core categories illustrated in Table 19. Each section first presents the findings based on interviewees' insights, ensuring their perspectives are accurately captured. These findings are then analyzed in relation to existing literature, highlighting alignments, discrepancies, and potential contributions to deepen the understanding of the subject.

5.2.1. Profile of Respondents

Stakeholder Group	Abbr.	Nr.	Gender	Interview Format	Scope of Organisation	Location of Organisation	Language of Interview	Years of experience
Scientific Community	SCC	IR 1	w	Online	Governing	Germany	German	35
		IR 2	m	Online	Governing	Germany	German	10
		IR 3	m	Online	Individual	Germany	English	25
		IR 4	m	Face to face	Individual	Austria	German	30
Hotel Operation / Investor	HO/I	IR 5	m	Face to face	Individual	Germany, Austria	German	20
		IR 6	m	Online	Individual	Germany, Austria	German	10
		IR 7	w	Online	Individual	Germany	German	25
		IR 8	m	Online	Individual	Germany, Austria	English	20
Sustainability Expert	SUE	IR 9	w	Online	Individual	Austria	German	25
		IR 10	m	Face to face	Individual	Austria	German	20
		IR 11	w	Online	Individual	Germany, Austria	German	20
		IR 12	m	Online	Individual	Germany, Austria	German	30
Politics / Lobby	PO/L	IR 13	w	Face to face	Governing	Austria	German	30
		IR 14	w	Online	Governing	Austria	German	30
		IR 15	m	Online	Governing	Germany	German	30
		IR 16	m	Face to face	Governing	Austria	German	15

Table 20: Interview Participants Overview
Source: Author's own data

The four predefined stakeholder groups include a total of 16 information respondents (hereafter referred to as "IR"), whose profiles and key characteristics are presented in Table 20. The organization's location is mainly focusing on the Austrian (*n=6*) and German markets (*n=5*). Five companies in the respondents' set have properties or satellite offices across both regions. Because of the geographical focus of this study, the interview was conducted predominantly in German (*n=13*). Regarding gender, there is a slight tendency of male (*n=10*) compared to female respondents (*n=6*). The respondents' years of experience in sustainability matters ranged from 10 to 35 years, averaging around 25 years. The majority of the respondents work for an individual organization (*n=10*), whereas the SCC and PO/L stakeholder groups are predominantly owned by government institutions (*n=6*). The interviews were conducted between June and October 2023 and lasted between 37 and 62 minutes. The conversation format was predominantly online (*n=11*), and face-to-face interviews (*n=5*) took place on special request.

5.2.2. Environmental Awareness

Generally speaking, the German and Austrian hotel industry have a strong dynamic due to ESG regulatory and political interests. Furthermore, hotels are among the most polluting asset classes and possess distinct characteristics such as 24-hour operations with many co-interfering stakeholders such as guests, employees, or suppliers. Nevertheless, respondents argue that knowledge about environmental activities is minimal. This is partly due to the overall structure of the German and Austrian hotel industry, where close to 80% of all properties are SMEs and family-owned. Although some hotels prioritize sustainability, the majority continue to fall behind in implementation. IR15 adds that "*we must be clear that there are companies, small and large, that already do this quite fantastically and many hotels, large and small do far too little*"[19]. IR16 notes further that "*the typical hotel knows what is used for heating, and maybe they still know what the electricity kWhs are. In terms of waste generation there is no knowledge and certainly not in terms of water generation*"[20]. Others claim that hotels operated by international companies are more committed to sustainability efforts compared to smaller establishments. When asked to rate the level of ESG development in the German and Austrian hotel industry on a scale of 1 (non-existent) to 10 (exceptional), the majority of respondents indicate that it is at level 1. Identified resource consumption-saving techniques in use in the German and Austrian hotel industry are key card systems with energy cut-off in the room, temperature and light regulation in unoccupied rooms/areas, LED bulbs, low flow shower heads, or waste splitting systems. This is generally in line with green practices found in other geographical regions (Acampora et al., 2022; Manganari et al., 2016; Santiago, 2021). Though, respondents underline that these measures are not enough to align with ESG regulatory.

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[19] Directly translated, German quote: „*Wir müssen ja klar sein, dass es Firmen gibt, klein und groß, die das ganz fantastisch bereits machen und viele Hotels, groß und klein viel zu wenig machen*."

[20] Directly translated, German quote: „*Die breite Masse an Hotels sagt, ich weiß, womit ich heize, ich weiß vielleicht noch, was sind meine Elektrizitäts KWhs. Beim Abfallaufkommen gibt es kein Wissen und beim Wasseraufkommen schon gar nicht*."

The identified overarching goal for the industry is to define a starting point for measuring environmental data and intensity metrics for the broad mass of German and Austrian hotels and gradually introduce them to the topic. On the regulatory side, reporting non-financial information and preventing stranding assets, i.e., property devaluation caused by insufficient environmental activities, are key topics. Furthermore, environmental measures need to be placed on an accurate data basis. Otherwise, it might lead to poor business decisions and sub-optimal levels of resource efficiency. Despite measuring environmental data, respondents emphasize that storytelling by creating awareness for the guests as well as employees is crucial for performance improvement. However, reducing services or the quality of a hotel concept (e.g., limiting shower time to reduce water consumption) is not an option.

Regarding the multitude of environmental certificates available in the German and Austrian hotel industry , respondents underline that specific labels are making marketing for possessing ESG conformity without any valid KPIs or auditing from an official authority. Furthermore, the labels are not uniform in their data collection process. Nevertheless, an environmental label creates awareness for sustainability and helps especially SME hotels to encounter different aspects of sustainability. Furthermore, respondents of PO/L agree that the work of Sustainable Hospitality Alliance with the implementation of HCMI for carbon accounting, the HWMI for water measurements, and the HWMM for waste measurements are helpful and may be used as a foundation. Though, these frameworks are predominantly used by international hotel companies. Therefore, the hotel industry must start to measure and analyze their environmental performance uniformly. The respondents compare this ongoing process similar to the International Financial Reporting Standards (IFRS) for financial reporting.

Interviewees argue that, in light of the ESG Taxonomy and the non-financial reporting directive CSRD, there is a significant disparity between regulatory requirements and the actions hotels are actually taking. Furthermore, this discrepancy leads to confusion and a hold-still movement. However, it has to be acknowledged that 80% of the German and Austrian hotel industry are SMEs, and there are minimal to no obligations for SMEs arising from the current legislative framework. However, it is emphasized that SMEs have increased environmental reporting needs to financial institutions when applying for financing or meeting the demand of large corporate clients who must adhere to ESG regulations and, e.g., report on their Scope 3 emissions. Moreover, despite the largest hotel companies adhering to GRI standards for ESG reporting, there remains no universally accepted method of reporting. Furthermore, according to the experts, the status quo will remain unchanged in the future as ESRS states that intensity targets are formulated as ratios of resource consumption relative to a unit of physical activity or economic output without stating explicit indicators (see Chapter 3.1.2). Therefore, respondents agree that despite reporting according to GRI or other methodologies considering the ESRS, the operational measuring must be uniform. This asymmetric reporting strategy highlighted by Legrand et al. (2013) 10 years ago is still evident resulting in difficult comparison and benchmarking possibilities within hotel companies. In addition, an authority auditing environmental results is not evident, and a new profession, the auditor for sustainability reporting, must be desperately developed. Furthermore, it is highlighted that environmental practices are highly interlinked with social aspects (e.g., consequent training of employees, creating awareness) as well as governance aspects (e.g., auditing of environmental metrics). Recognition should be given to expanding the scope of credit in areas such as how ecological measures are treated, trained, and analyzed.

5.2.3. The Owner-Operator Dilemma

Another concern highlighted by the interviewees is the division between ownership and operational management. While in other parts of the world, the manager of the hotel acts within a management contract on the owner's bill or the owner enters franchising with an international hotel company, in the German and Austrian hotel industry the lease contract is dominant. There, the lessee rents out the property to the lessor and receives (an often fixed) amount of rent with no operational responsibility (Almeida et al., 2022). The associated lease term is generally 25 to 35 years, and reporting financial and commercial activities from the operator side is generally limited. Consequently, most of the existing contracts do not have any clauses referring to environmental sustainability or hardware upgrade of the property for environmental reasons included. Therefore, implementing measures is even more complicated in this contract situation and needs active contractual negotiation with operators to establish data consumption management. Respondents on the owner side were forced to establish ESG measures due to rising obligations of EU Taxonomy increasingly negotiated clauses within the Coronavirus crisis, where often lease payments were prolonged or suspended. However, actively interfering in the hotel business is not in the landlord's interest. Hence, the oversight and monitoring of environmental measures are constrained. Whereas environmental reporting is one aspect, another challenge is the investment question when the property receives hardware upgrades (e.g., photovoltaic panels, window insulation, heat pump). Therefore, respondents argue that environmental demarcation lists would help clearly associate any enhancements to either the owner or the operator. IR12 from an institutional real estate investor underlines that tremendous technical installations are necessary to cover the environmental gap from the status quo and align with ESG regulations. According to the interviewees, the solution to the dilemma lies in the incentive structure, as motivation is lacking when the operator pays a fixed rent to the owner, and the owner is not bound by non-financial reporting obligations. As a result, the owner and operator need to work together to make the property more environmentally efficient. This challenge and its implications are not addressed in the existing literature, highlighting a gap on sustainability incentives in the hotel industry.

5.2.4. Measuring Practices

As previously noted, measuring currently takes place within a manual process of the collected invoices and is, therefore, not automated via smart meters. IR3 adds "*if you look at 80% being small private-owned, private-run businesses, energy and water measurements are manually done, if it's done at all*". Although collecting data only happens sporadically, a human error in reading, transferring, and analyzing the data may be evident. All interviewees agree, that the installation of smart meters is preferable. However, a few obstacles are mentioned within an already existing property. First, installing smart meters is costly, and it is not agreed upon who pays the investment (see section 5.2.3). Second, especially within the German and Austrian hotel industry, some hotels are protected through historic preservation and are thus limited in installing smart meters or photovoltaic panels. Third, the zoning of smart meters is complex within existing buildings. Finally, human capital and rigid software must be developed to read, analyze, and process the data collected from smart meters. Another possible option is to upgrade the analog meters with a camera and Optical Character Recognition (OCR). This technology recognizes text within a digital image and directly transfers data to an environmental dashboard. Regarding resource consumption savings, the existence of a BMS has been highlighted. Those systems are "intelligent" microprocessor-based networks installed to control and monitor the building's technical systems, such as lighting, heating, cooling, ventilation, and many more (Domingues et al., 2016). As these components are centrally directed, data can be transferred per minute. While there are no official statistics of hotels that installed a BMS, respondents estimate that these are less than 1%. Furthermore, upgrading to a BMS in existing buildings is almost impossible.

When it comes to visualization of results, respondents argue that there must be an easy-to-understand system for all stakeholders involved. Therefore, a traffic light assessment is feasible when creating KPIs. In other words, despite the actual intensity metric result, a green light indicates an improvement, a yellow light a stable development, and a red light shows a decrease compared to last year or the peer group. Furthermore, the indicators should be displayed separately within a real-time dashboard. There, absolute figures, intensity metrics as well as internal and external benchmarking should be integrated to display the environmental journey. An example of an environmental dashboard of an institutional real estate investor is shown in Figure 17.

Figure 17: Metrics Vizualisation Example
Source: Author's own data

5.2.5. Development of Intensity Indicators

When asked what should be measured within a hotel property to adequately meet reporting obligations of the environmental part of ESG reporting, interviewees underline that the environmental part is the most discussed and significant part. There, respondents state that energy, water, waste and subsequently GHG emissions are necessary to comply with environmental reporting. According to the interviewees, energy consumption is currently the most important resource for hotels in Germany and Austria. From the guest perspective, displaying and communicating GHG emissions is the most relevant, according to the SUE respondents. As a result, the conducted literature review on topics that need investigation in the form of EGWW metrics aligns with results from the preceding qualitative interviews.

When it comes to the development of measurable intensity indicators, the interviewees agree that the asset-class hotel is different from other real estate assets and needs distinct indicators to measure environmental performance. Likewise to the literature, respondents underline that indicators must be relevant, easy to measure and analyze, and quantifiable (Nesticò and Maselli, 2020). Furthermore, existing frameworks, initiatives, and legislative regulations need to be addressed and included within a KPI framework. So, the focus is to comply with existing initiatives and make them feasible for the fragmented SME hotel industry. Last but not least, operational needs and hardware conditions must be acknowledged and recognized. Due to the stated reasons, creating uniform indicators is challenging.

Similar to the literature (Anand and Kodali, 2008), respondents argue that internal benchmarking, as well as benchmarking against competitors or peers, is the most common process. Consequently, either the journey of the development of the KPIs is tracked with specific goals (e.g., reduction of energy intensity by 2% each year) or a specific peer group with similar characteristics is established and benchmarked against. The latter needs valid clustering to gain comparable results, which is further elaborated in Chapter 5.2.6. For internal benchmarking, historical data on KPIs is necessary. It is advisable to collect data from the last three business years. When measuring environmental figures, interviewees emphasize that either absolute figures are tracked or metrics are formed. Though, it must be acknowledged that absolute figures limit both internal and external comparisons and lack informativeness. Furthermore, measuring not only on a cost basis but also on a consumption basis increases comparisons with other properties regardless of their contract remuneration. Regarding metrics formulation IR15 states accurately "*make it easy and relevant, you can always improve*". Therefore, respondents argue that a starting point, a first simplified set of metrics, must be implemented. Initially, the collected data may exhibit a degree of imprecision, but it should, at the very least, yield a numerical value for subsequent analysis. The greater the level of detail in data and metrics, the more insights a hotel can extract, but this complexity may become overwhelming. Therefore, along the way, the numbers can be improved in accuracy and data depth by using technology as an enabler. Furthermore, with intensity metrics, the success control, i.e., the observation of set environmental measures, can be tracked easily. Therefore, interviewees argue that creating intensity metrics is best for benchmarking environmental performance. However, valid resource input and reference unit variables are necessary as well as the clustering process must be comprehensible to gain a peer group to benchmark with. Furthermore, respondents primarily focus on internal benchmarking, as there was minimal cross-reference benchmarking among them due to the absence of shared data. One respondent argues that absolute figures are tracked and only anomalies (e.g., technical and hardware errors) are recognized and reported.

Even though relevant indicators are measured, the hotels need human resources to analyze as well as formulate recommendations and implementation strategies. Respondents underline that the coupling of data and implementation strategies is currently nonexistent, especially within SME hotels. With implementation comes awareness, and IR15 argues that "*50% of any development is awareness*". Therefore, the training of awareness on environmental topics is key to improving metrics performance, which was also underlined by existing literature (Beccali et al., 2009; Hu et al., 2015). Furthermore, respondents generally add that benchmarking is always backward-looking, i.e., measures can only derive from already incurred incidents. Last but not least, respondents highlight that resource consumption values from 2020 and 2021 are highly distorted due to the Coronavirus pandemic and the associated closing times of the hotels.

5.2.5.1. Energy Intensity Metrics

When asked about the most commonly used environmental metric, interviewees identify energy consumption as the most prominent and widely measured indicator. This result is similar to the number of academic studies issued and discussed in the SLR. Despite the increasing reporting requirements caused by the EU Taxonomy, a further increase in the relevance of energy-related figures was observed due to the rise in energy costs in 2022. The "Energieausweis," an energy certificate measuring energy efficiency, is relevant to the energy efficiency in the operation of real estate. Foundations are regulated in *Directive 2010/31/EU of 19 May 2010* and transformed into national law. When renting or selling a building, issuing the energy certificate is obligatory, but not during operations. The energy certificate shows the heating requirement, primary energy demand as well as carbon dioxide emissions on a scale from A+ to H (Kuchar, 2014). The reference unit is similar to the EUI intensity metric measured by floor area. PO/L respondents that nearly 2/3 of all hotel properties do not possess an energy certificate. Despite the measuring of energy consumption, creating awareness among employees is highlighted. Specific energy reduction training must take place depending on the installed hardware of the hotel. This may include internal energy reduction measures such as reducing stove running time in the kitchen, as well as within guest areas such as sauna opening hours.

Resource Input

All interviewees acknowledge that the hotel must display its primary energy consumption to gain a valid absolute figure. Despite the total consumption, it is vital to assess what kind of energy sources (e.g., electricity, gas, oil, and heating) are used. This is crucial for GHG footprint calculations as well. For internal benchmarking, historical data (3 years) per energy source is essential. This finding is generally in line with studies relating to measuring energy consumption and reporting of international hotel companies. Nevertheless, when hotels are producing their own energy through heat pumps or photovoltaic panels it should be accounted for to generate a total energy consumption of the hotel. Sourced electricity, which is then not used but fed in ("sold energy"[21]) into the local electricity network, must be deducted. Furthermore, respondents argue that the display of the share of renewable energy (i.e., Green Gas, Green Electricity) must be visible. When asked about their measurement habits, hotels rarely use direct measurement via smart metering, as most still rely on analog energy meters. The SO/I group argue that newer built hotels (> 2015 building age) possess smart meters, and older buildings are occasionally upgraded. Nevertheless, respondents agree that most of the measuring of energy consumption in German and Austrian hotels is still indirect from the invoicing rather than from direct data from smart metering. This result is similar to academic studies measuring energy consumption and using billing information as a basis data (Deng and Burnett, 2000; Pieri et al., 2015; Shiming and Burnett, 2002; Yao et al., 2015). Similar to previous studies conducting energy consumption measurements (see for example Bohdanowicz and Martinac, 2007; Lai, 2016; Santamouris et al., 1996) all respondents state that the unit to measure energy within the hotel industry is kilowatt-hours (kWh).

Reference Unit

Table 21 presents the primary findings derived from the respondent data, highlighting the dominant reference unit variables, as indicated by an "x" in the corresponding fields. Energy consumption is most commonly measured relative to floor area, aligning with the EUI metric and prevailing academic practice. Respondents justify this by noting that major energy loads, e.g., heating, cooling, ventilation, and lighting, are generally independent of occupancy. This finding aligns with prior studies reporting a low correlation between occupancy rates and overall energy consumption. Second, institutional investors highlight that to gain comparability with other asset classes (e.g., residential, office, retail), the floor area intensity metric is critical. However, it is argued that the energy consumption per floor area is not tangible to satisfy the needs of the asset class of hotels. Furthermore, the intensity metric EUI is not suitable for guest communication practices. As a result, an occupancy-related metric must be included, where energy consumption is measured per guest night (7/16) or by occupied room (6/16).

[21] Numerous challenges are identified in the implementation of this practice. First, particular attention must be given to the installation of photovoltaic (PV) systems, as there is no revenue generation associated with rental or leasing. Furthermore, distinct regulatory and tax implications arise when energy is fed into the domestic electricity grid. However, a detailed examination of these considerations is beyond the current scope of discussion.

Both indicators can be used somewhat across all types of hotel concepts, regardless of the operating type, location, and seasonality. Nevertheless, it must be acknowledged that different room sizes and the number of guests within a room may distort the indicator. Therefore, a measurement per guest is recommendable.

	SCC				HO/I				SUE				PO/L			
	IR 1	IR 2	IR 3	IR 4	IR 5	IR 6	IR 7	IR 8	IR 9	IR 10	IR 11	IR 12	IR 13	IR 14	IR 15	IR 16
Rooms																
per floor area	x	x	x		x	x		x	x		x	x	x	x	x	
per occupied room					x	x		x	x		x	x	x	x		
per room										x						
per guest night	x	x		x			x						x		x	x
per employee													x			
per mio. net revenue			x													
Food & Beverage																
per floor area	x	x														
per cover	x	x														
per seat				x												x
per employee																

Table 21: Comparison Reference Units Energy
Source: Author's own data

IR12 state that air volume should be taken to benchmark energy consumption. This is due to the different sizes and room heights of hotels. However, this variable is not being tracked by hotel operations or real estate owners, so this idea has not been further evaluated. Two respondents highlight the matrix approach to benchmark energy consumption by splitting by per guest night, per occupied room, per floor area, and per employee. Similar to previous literature (Xuchao et al., 2010), some respondents argue that the energy consumption reference variables must be split between public and rooms area or between F&B and rooms area. Four respondents (IR1, IR2, IR4, IR16) argue that the F&B department must be seen separately and energy consumption must be divided by seat numbers. When asked why the number of F&B covers (number of guests) is not appropriate as a variable, it is found that most restaurants/hotels do not track this number. Furthermore, the splitting of outlets always comes with the question of the quotas of splitting. Several respondents argue that hotels do not possess the floor area numbers in total or of their respective outlets, which may result in non-valid indicators. IR4 claims that a fixed quota is necessary (80% Rooms, 20% F&B), which is not practicable caused by the highly fragmented number of outlets within the industry and is therefore rejected by other respondents.

Additionally, several interviewees emphasize the relevance of measuring energy intensity in relation to net revenue, identifying it as a key reference variable that warrants further investigation to enhance the financial-contextual comparability of sustainability performance. This is the dominant intensity metric of the ESG frameworks such as GRI and is included in the ESRS (e.g., ESRS E1-5 Energy Intensity). IR3 argues that this intensity metric is a feasible financial normalization to benchmark against other hotels, asset classes, and even other sectors. Basically this intensity metric measures resource efficiency, i.e., how much revenue is generated from the invested environmental resource. This figure is highly relevant to complying with sustainability reporting regulations. However, in the day-to-day business of a hotel and in terms of communication with guests, this variable is not perceived as appropriate. As a result, the energy consumption of hotel operations should be measured per floor area and guest night. Depending on data availability, splitting different outlets per floor area (Rooms / F&B / Wellness / Other) is preferable. Furthermore, the energy intensity based on net revenue is necessary for environmental non-financial reporting.

5.2.5.2. Water Intensity Metrics

While numerous scholars emphasize the growing scarcity of water and the corresponding need for reduction measures (Atay and Saladié, 2022; Gössling et al., 2012; Sofroniou and Bishop, 2014), interviewees suggest that this issue is perceived with less urgency within the German and Austrian hotel industry, where it is often diminished by key stakeholders. For example, commonly water systems (e.g., toilet flush, gardening) in Germany and Austria work with fresh water. This leads to the fact that water recycling or greywater reuse is close to non-existent in the hardware of the real estate and hotel operations. Grey water is generally measured indirectly by a sewage fee which is calculated from the total water consumption and paid to the municipality. Therefore, no measuring device for greywater is generally installed within hotel properties. Only one respondent of HO/I possesses a rainwater re-usage, own spring as well as grey water metering. Furthermore, the purpose of the water, e.g., hot water production and water for landscaping, is not separated. Nevertheless, interviewees contend that these systems have the potential to significantly reduce water consumption. Monetary subsidies to foster water-saving initiatives and hardware upgrading would increase transposition rates. However, existing solutions that require minimal hardware upgrades include water-saving showerheads, flow-limiters in toilet flushes, and pressure reduction in water pipes. Furthermore, the sustainability training of employees is highlighted. Examples of wasteful water consumption are repeatedly flushing the toilet during cleaning, draining water non-stop when cleaning the bathroom, or using hot water to thaw frozen food.

Likewise to the literature, respondents agree that the quality level of a hotel and guest behavior influence water usage. Nevertheless, HO/I argue that it is essential to be cautious when installing systems that reduce the guest experience (e.g., pressure reduction in water pipes), especially in luxury hotel categories. Splitting water usage according to hotel outlets as proposed by Gössling (2015) is favorable but would need extensive hardware investment. However, it is argued that the integration of this approach should be mandated by law for all newly constructed hotel buildings.

Resource Input

Due to the reasons mentioned in the previous section, water measurement is reduced to measure total water usage by adding internal and external water consumption. This is done by reading the water metering system of a hotel. When a hotel possesses systems such as rainwater re-usage or its own spring, grey water must be measured to accurately account for its sewage fee. As a second step, recycled as well as grey water metering should be integrated and displayed as a percentage of total water consumption. Furthermore, metering according to outlets of a hotel (e.g., Rooms, restaurant, wellness, conference) should be anticipated. Though, this metering involves hardware upgrading. As a third step and in the long run, likewise, to Scope 3 emissions, interviewees argue that a supply chain perspective must be integrated by measuring the water consumption of total activities (e.g., food feeding, suppliers, guest journey). As a starting point, respondents argue that external water withdrawal should be consequently measured and benchmarked. When internal water sources exist, a metering device should be added to gain total water consumption. In terms of water metrics, liters are the predominant reporting unit, aligning with conventions established in previous studies on hotel water consumption (Becken and McLennan, 2017; Deyà Tortella and Tirado, 2011; Ruiz et al., 2021). However, there is a growing tendency to use cubic meters (m^3) as an alternative unit of measurement, as noted by four respondents. This choice often depends on the volume of consumption and prevailing billing regulations. Additionally, the CSRD mandates reporting in cubic meters, further reinforcing its relevance.

Reference Unit

In terms of reference unit variables i.e., the variable of which water withdrawal should be divided, the results are visible in Table 22. Interviewees generally argue that water usage is strongly related to the occupancy level of a hotel property. IR3 describes accurately that "*the link between water usage and occupancy is maybe stronger than the link between water usage and square meters*". While some may consider tracking floor area as a control variable, the key variable for accurately representing per person usage is the consumption per guest night or per guest. IR5, IR9, IR13, and IR15 conclude that per occupied room is most valid. However, the generated intensity indicator may be distorted due to different room categories and associated number of guests occupying one room (e.g., single room, double room, four-bed room).

	SCC				HO/I				SUE				PO/L			
	IR 1	IR 2	IR 3	IR 4	IR 5	IR 6	IR 7	IR 8	IR 9	IR 10	IR 11	IR 12	IR 13	IR 14	IR 15	IR 16
Rooms																
per floor area	x										x		x	x		
per occupied room			x		x			x	x				x		x	
per room																
per guest night	x	x		x		x	x	x		x	x	x	x	x		x
per employee													x			
per mio. net revenue																

Table 22: Comparison Reference Units Water
Source: Author's own data

The findings are displayed in Table 22 and are in line with recent academic studies discussing the water consumption of hotels (Alhudaithi et al., 2022; Cunha and Oliveira, 2020; Díaz Pérez et al., 2019; Gabarda-Mallorquí et al., 2017; Mclennan et al., 2017). Measuring energy consumption per unit of floor area is particularly valid for hotels with extensive facilities, such as multiple restaurants, pools, spa areas, or large conference spaces. In such cases, a disaggregation of energy use by specific floor area categories is necessary to ensure accurate and meaningful analysis. Likewise to energy consumption, the water intensity by net revenue is necessary to be tracked to be compliant with the EU Taxonomy (E3-4 Water consumption).

5.2.5.3. Waste Intensity Metrics

When asked about waste-related measurement, interviewees consistently acknowledge the presence of waste management initiatives, such as waste segregation and zero-food-waste campaigns. However, they also identify significant opportunities for improvement in waste measurement and tracking within the German and Austrian hotel industry. Though, it has to be acknowledged that the measuring and splitting of waste are more complex than energy and water-related figures. Despite the fact that waste management systems are not uniform throughout the EU, there are even significant differences between municipalities across countries. SCC and HO/I argue that in the German and Austrian hotel industry measurement is done via the invoicing of the waste disposal company. Furthermore, it is highlighted that figures are inconsistent as waste management is dependent on the location of the hotel and the waste disposal company. There are two systems existent; for example, in Austria, rural areas weigh the container content itself (which generally generates a more accurate result), and more urban areas (e.g., the city of Vienna) invoice per container regardless of the actual content (e.g., 1,100 liters standard container). The latter may result in not fully filled containers and, therefore, distorted values. There, a compressing device for waste could be useful, which is generally not present in German and Austrian hotels.

Another challenge highlighted by SCC and HO/I respondents is the lack of visibility and traceability of the waste stream, i.e., the origin of the content of the container. Furthermore, several interviewees emphasize the value chain approach i.e., that hoteliers are strongly dependent on the packaging of suppliers as well as HACCP[22] regulations in their operations. In addition, because of these regulations, the distribution of already prepared food to people in need is limited. Accordingly, the need for a harmonized European waste management framework grounded in circular economy principles is strongly emphasized. To the contrary of previous studies measuring waste consumption by a manual or direct process (Ball and Taleb, 2011; Debnath, 2015; Papargyropoulou et al., 2016; Camilleri-Fenech et al., 2020), hoteliers mostly measure with an indirect method. Whereas SUE respondents argue that hoteliers should weigh their waste independently, in the day-to-day business, they mainly rely on the invoicing of the waste disposal company. Due to time constraints, manual measuring with intelligent scales is done rarely. In addition, the records and benchmarking of waste measurement are very limited. This finding underlines the necessity of more studies related to waste measuring and implementing separation strategies.

Regarding the separation of waste, different types of waste are generally separated. However, the hotel often cannot implement its own waste management strategy as waste disposal companies cannot recycle them properly. Moreover, there is generally a lack of employee training and systematic monitoring to ensure proper implementation of waste separation practices. Another critical factor influencing waste management is guest behavior, which underscores the need for a broader societal shift in consumption attitudes and practices, such as those related to buffet-style food service.

[22] Hazard Analysis Critical Control Points (HACCP) provides a management framework for monitoring the food chain system of a hotel to reduce the risk of foodborne diseases (Food and Agriculture Organizaton of the United Nations, 2023). Since January 2006 mandatory, the implementation and constant adaptation of HACCP control system is regulated in REGULATION (EC) No 852/2004 of the European Parliament and of the Council on the hygiene of foodstuffs.

Resource Input

Several obstacles are discussed above regarding the input variables of waste management, i.e., the actual types of waste that should be benchmarked. Nevertheless, respondents argue that waste is separated according to its kind and source. Table 23 presents the respondents' findings regarding the types of waste separation that should be measured.

Waste Type		IR 1	IR 2	IR 3	IR 4	IR 5	IR 6	IR 7	IR 8	IR 9	IR 10	IR 11	IR 12	IR 13	IR 14	IR 15	IR 16
Non-hazardous	Residual	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	Glass		x	x		x	x	x	x					x	x		
	Paper	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	Cardboard			x													
	Metal													x	x		
	Plastic	x	x	x		x		x	x	x	x	x	x	x	x	x	
	Food	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Hazardous	Oil		x												x		
	Other	x		x					x	x					x		
Only total waste																	x

Table 23: Waste Input Variables Respondents
Source: Author's own data

Generally speaking, hazardous and non-hazardous waste can be differentiated. The latter is waste material that is non-harmful to health and the environment and consists of either glass, paper, cardboard, metal, plastic, or residual waste. All respondents agree that organic food waste, paper, and residual waste must be split. Other waste materials can be grouped together e.g., cardboard and paper. IR16 states that only total waste is collected by hotels because a uniform split is not possible. Hazardous waste is materials that have characteristics of chemical, physical, and biological hazards and are commonly harmful to health and the environment (e.g., radioactive waste, batteries, paint) (Hussain et al., 2022). According to the interviewees, although cooking oil is consumed within hotel operations, hazardous waste in the German and Austrian hotel industry is not systematically recorded and is typically managed through separate recycling processes. Consequently, only cooking oil is considered in the assessment of environmental sustainability. The identified prevailing reporting unit is similar to previous studies (Ball and Taleb, 2011; Debnath, 2015; Puig et al., 2017) and hence measured in kg. However, this is strongly related to the billing of the waste company, where in some regions (e.g., Western part of Austria) reporting in liter is standard. Interviewees underline that recalculation from liter to kg and vice versa is impossible.

Reference Unit

The findings regarding reference variables are illustrated in Table 24. All respondents agree that waste consumption greatly depends on the usage of the hotel real estate, i.e., corresponding to the occupancy level of specific areas. Nevertheless, as previously noted, the waste stream is not visible. Therefore, splitting according to areas of the hotel is not possible. As a result, the reference metric "per guest" is preferred for hotel-related non-hazardous waste. The majority of organic waste comes from food preparation and consumption. Therefore, the F&B department should be analyzed separately, and the dominant reference variable should be identified as per cover, i.e., the number of guests within the F&B outlet. When this data is unavailable, the number of seats within the F&B areas should be taken. If both are not available, the total waste consumption should be measured.

	SCC				HO/I				SUE				PO/L			
	IR 1	IR 2	IR 3	IR 4	IR 5	IR 6	IR 7	IR 8	IR 9	IR 10	IR 11	IR 12	IR 13	IR 14	IR 15	IR 16
Rooms																
per floor area	x										x					
per occupied room	x															
per room																
per guest night		x		x	x	x	x	x	x	x	x	x	x	x	x	x
per employee													x			
per mio. net revenue																
Food & Beverage																
per floor area	x										x					
per cover	x	x			x	x	x	x	x	x	x	x	x	x		x
per seat				x											x	
per employee													x			

Table 24: Comparison Reference Units Waste
Source: Author's own data

Although the dominant reference variable is in line with previous academic studies (Ball and Taleb, 2011; Debnath, 2015) and industry initiatives such as the HWMM (Sustainable Hospitality Alliance, 2021), reporting practices of the international hotel industry still differ in measuring waste consumption per floor area (Hilton Worldwide, 2021). The interviewees noted that measuring total waste in relation to net revenue is not mandated by the ESRS regulations; however, it is recommended to promote consistency with energy and water-related environmental tracking practices.

5.2.5.4. GHG Emissions Intensity Metrics

When measuring GHG emissions, all respondents underline the objectives of the EU Taxonomy to prevent Greenwashing. IR3 argues that "*if we consider that 80% of the hotels are privately owned and operated, I don't know what the number is of hoteliers that understand Scope 1 and 2 or ultimately the contents of Scope 3, and that actually track and measure and report. It is probably extremely low.*" Consequently, there was consensus that most hotel operators/owners in the two countries do not track their GHG emissions and generally do not know the sub-areas that need to be queried to gain valid calculations. However, a few hotels have started this process with the help of external service providers or as part of a sustainability certificate. Several respondents argue that these GHG accounting methodologies are not yet mature and that a uniform standard is necessary for the hotel industry. Current practices of hotels fostering sustainability mainly involve compensating guests' GHG emissions or reducing prices when the guest arrives environmentally friendly (e.g., via train, bike, or by foot).

Regarding the GHG measuring process, interviewees from SCC and SUE underline that the published guidelines of the HCMI with the splitting according to the Greenhouse Gas Protocol (see Chapter 3.3.4) are already in use with institutional hotel owners as well as international hotel operators. However, awareness of the smaller, privately owned premises is limited. It can be concluded that the calculation scheme exists, but the data needed is still missing. While Scope 1 and 2 emissions can be tracked, there is still a giant black box when calculating Scope 3 emissions. The latter is currently measured partly with rough estimations regarding guest and employee journeys. This is due to needing regulations to capture the guest journey, e.g., through an obligatory reporting system. To achieve this goal, the proposed solution is to integrate a journey tracking system into the check-in arrival form. Furthermore, Scope 3 emissions can only be partly influenced by the hotelier (e.g., distance of journey of guests, means of transport). These findings are congruent with the current practices of international hotel companies (see Chapter 3.6).

What is more, double-counting, i.e., GHG emissions are counted more than once depending on the level of the supply chain, is an issue in Scope 3 calculations. IR2 proposes that this could be similar to the same value-added tax (VAT) system process, where the end consumer carries the whole carbon footprint. Within Scope 1 and 2 emissions, respondents argue that measuring is mainly done by recalculating existing data (e.g., the energy sources into kgCO_2e). Chain affiliation generally increases the probability of tracking GHG emissions Scope 1 and 2 according to SUE and HO/I. Nevertheless, it is observed that institutional hotel owners managing portfolios exceeding

100 properties frequently do not report the greenhouse gas emissions of their assets, primarily due to limited internal analytical capacity. This raises important questions regarding the feasibility of comprehensive GHG reporting for SMEs, which typically have access to even fewer resources and technical expertise.

Resource Input

The preferred input variables should be clustered according to the Greenhouse Gas Protocol as well as the PAS 2050 standard and, therefore, divided into Scope 1 (direct emissions), Scope 2 (indirect emissions), and Scope 3 (supply chain emissions) (GHG Protocol, 2023). This is generally in line with previous academic studies of GHG consumption measuring of hotel real estate (Díaz Pérez et al., 2019; Filimonau et al., 2021; Huang et al., 2015; Hu et al., 2015). As previously discussed, respondents argue that Scope 1 and 2 can be measured with already existing data, Scope 3 emissions are still rough estimations and depends on a multitude of factors along the value chain (e.g., suppliers, guests journey etc.). Therefore, measuring Scope 1 and 2 is preferred as a starting point. The partial integration of Scope 3 (e.g., GHG data of external laundry) is feasible, depending on data availability. Figure 18 illustrates the finalized model differentiation of scopes, as derived from the insights provided by the interviewees, specifically tailored for the hotel industry.

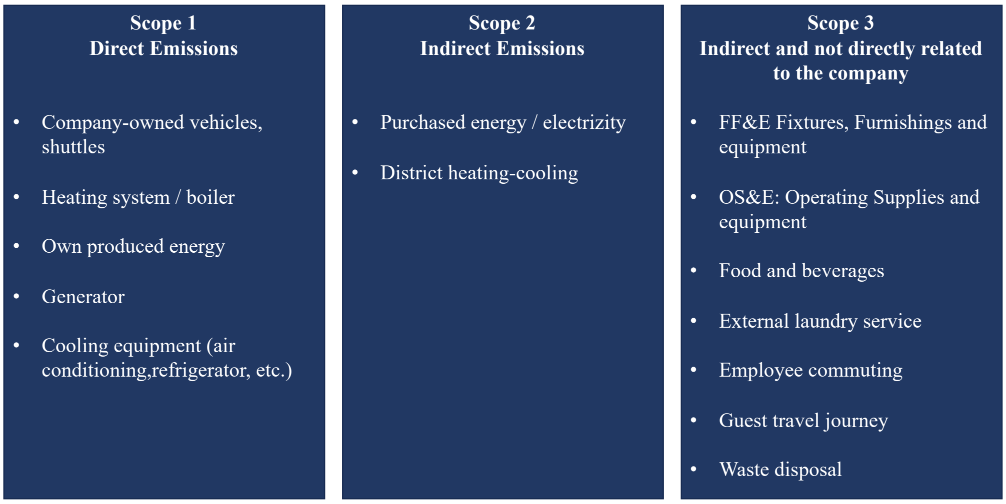

Figure 18: GHG Scope Differentiation for the Hotel Industry
Source: Author's own data

Reference Unit

As previously discussed, the measurement of GHG emissions is still in its early stages, and accordingly, the findings related to reference variables remain limited. The results are presented in Table 25. Generally speaking, Scope 1 and 2 emissions are strongly related to energy sources; respondents partly argue that the preferred reference variables are similar to the ones discussed in the energy section. However, the floor area variable is less frequently reported, necessitating the inclusion of an occupancy-related variable. While the HCMI uses per occupied room as benchmarking value, respondents state that a measurement per guest or guest night is preferred. This is due to the fact that the EU Supply Chain Act asks for guest journey emissions, and corporate clients increasingly must calculate their GHG emissions on a per-employee basis for their company to comply with EU Taxonomy. This variable aligns with previous studies measuring GHG emissions (Filimonau et al., 2021; Salehi et al., 2021; Puig et al., 2017). Furthermore, to comply with ESRS, the GHG footprint must be measured against the net revenue in million (ESRS E1-6 Gross GHG emissions intensity).

	SCC				HO/I				SUE				PO/L			
	IR 1	IR 2	IR 3	IR 4	IR 5	IR 6	IR 7	IR 8	IR 9	IR 10	IR 11	IR 12	IR 13	IR 14	IR 15	IR 16
Rooms																
per floor area	x		x					x			x	x				
per occupied room			x			x		x			x			x		
per room																
per guest night	x	x		x	x		x		x				x		x	x
per employee									x							
per mio. net revenue																
Food & Beverage																
per floor area	x	x														
per cover	x	x														
per seat				x												x
per employee																

Table 25: Comparison Reference Units GHG
Source: Author's own data

5.2.5.5. Reporting Frequency

Regarding reporting frequency, i.e., how often the resource consumption should be measured, interviewees highlight the difference between reporting obligations (e.g., for CSRD) and the operational management needs of a hotel property. At a minimum, around 80% of respondents argue that the frequency should be similar to the annual financial statements. Respondents from SUE and HO/I highlight that to gain operational control possibilities to mitigate consumption ultimately, data collection should be done quarterly (*n=3*), monthly (*n=4*), or even daily (*n=2*). When asked about the reasons, the reporting frequency is dependent on different aspects. First, technology and automation play a crucial role in data collection. When there is smart metering or a BMS throughout the building, reporting and operational management are more accessible than collecting data manually, and thus, reporting is more frequent. Second, reporting frequency depends on the stakeholder who receives reporting. Financial institutions and investors typically require quarterly or yearly reporting, while the hotel operations a more frequent reporting is anticipated to adapt adequately. Nevertheless, PO/L and SUE argue that the more EU Taxonomy regulations there are, the more frequent and detailed reporting needs to be. Third, more frequent reporting is preferable in day-to-day operations, creating awareness of the environmental pathway for different stakeholders such as employees, suppliers, and guests. Furthermore, hands-on comparisons ease the way of communication (e.g., 50 tons of waste equals 10 elephants). Fourth, when a hotel has seasonal differences or is closed (one-season hotels), the reporting must be aligned with the opening days. Lastly, the availability of data where widely available numbers are more accessible to report daily, whereas less frequent reporting is attainable in waste-related figures. The findings generally align with the previous academic studies, where larger samples with widely available data (e.g., EUI measurements) typically build on annual data (Becken and McLennan, 2017; Bohdanowicz and Martinac, 2007; Santamouris et al., 1996) and more in-depth (single-) case study reports on a more granular basis (Cabello Eras et al., 2016; Chan, 2009; Prasad and Singh, 2015).

With regards to accessibility of data, respondents highlight that it strongly depends on the hardware installed within the hotel property. However, energy, water, and waste consumption data are easily available from the invoicing or the installed analog meters. HO/I and SUE respondents argue that even though the data is illustrated on the invoices, they have not been further analyzed or worked with. Furthermore, the human factor and fault probability play an important role in the manual processing of data. The data collection process is manual and may result in distorted values. External companies are needed to generate a valid GHG measurement, and depending on which Scope, it takes more work to receive reliable data. If data availability increases, actions can be taken by hotel management to reduce the environmental footprint. To conclude, basic data are available, but hotels have failed to use them. As a result, valid data on a more granular basis is always dependent on the availability of data, the installed hardware, the chosen benchmarking set, and their reporting frequency.

Therefore, as a starting point for environmental reporting, a reporting per anno is recommended, which corresponds to the previously conducted academic studies and the reporting period of the CSRD/ESRS. If an intelligent BMS with smart meters is installed real-time tracking is possible. Another option is to differentiate between sectors. Upgrading energy and water meters via OCR allows for the collection of data daily and helps reduce consumption, increase efficiency, and detect faults (e.g., water leakages in the hardware structure). The measurement of waste and GHG emissions is inherently more complex and, as a result, is typically conducted on a quarterly or annual basis.

5.2.6. Clustering of Environmental Data

The second section of the interview questionnaire addresses clustering, particularly in distinguishing data points (i.e., hotels) and categorizing them into groups of similar entities (i.e., clusters of comparable hotels). Several challenges have emerged in the clustering of environmental data for hotel real estate. First, interviewees argue that the hotel industry is highly heterogeneous and fragmented. Therefore, it quickly becomes complex depending on clustering criteria, and a too-narrow peer group must be prevented. Thus, easy-to-use and comprehensible clustering categories must be established to foster applicability and minimize potential errors. Second, a clustering standard must comply with industry standards and legislative regulations. Third, a matrix structure with several layers of clusters to see all parameters at a glance is preferred. Therefore, the establishment of minimum criteria and optional criteria is anticipated. Fourth, IR15 stated: "*Walk before you run. So we need to start where and not tear everything down immediately*". Hence, a clustering system must not be finished in the beginning; it can be a starting point where readjustment is possible over time. As a result, comparability is essential; although it is understood that no two hotels are entirely alike, a sense of comparison can still be derived. When applying the identified intensity indicators, all respondents identify different characteristics of hotels that need to be distinguished to gain a valid benchmarking set. Similar to previous academic literature, a splitting in real estate characteristics ("Physical factors") as well as hotel management operations ("Operational factors") is necessary when clustering environmental data and to gain a valid benchmarking set. A third category, "External factors," has been integrated to display other relevant clustering-related factors.

5.2.6.1. Operational Factors

Operational factors are associated with the operational management of the hotel property. The first identified aspect is the quality level of the hotel. As previously noted by different researchers (Barberán et al., 2013; Nguyen and Rockwood, 2019; Xuchao et al., 2010; Yao et al., 2015), the quality strongly influences all environmental figures and must be recognized. There, the measurement in the star rating (1 to 5 stars) of Hotelstars Union[23] is preferred (Hotelstars Union, n.D.). A rating according to the rate level and respective peers in close proximity should be done if a hotel is not star-rated. This finding is similar to several scholars who found a high correlation between quality level and resource consumption (Huang et al., 2015; Nguyen and Rockwood, 2019; Priyadarsini et al., 2009; Tsai et al., 2014). Likewise to the literature (Oluseyi et al., 2016; Tang et al., 2016), respondents agree that the quality level also determines the service offer, outlets, and number of hotel employees. Furthermore, associated with the quality of the hotel is the type of board, i.e., whether the hotel offers only breakfast, half-board, or full service. The central operating concept, whether the hotel is a city or leisure hotel, is indicated as another significant characteristic. Interviewee insights indicate that further differentiation within the leisure hotel sector, particularly between conference-oriented and wellness-oriented operations, is advisable as this distinction significantly influences resource consumption. The overall operating concept defines the type and number of outlets a hotel offers. In this context, resource-intensive outlets, such as expansive gardens and comprehensive wellness areas, receive particular emphasis. Due to limited data availability, a more granular differentiation, such as the number of dishwashers or saunas, remains unfeasible.

The utilization level of the building must be displayed, and therefore, an occupancy-related variable must be collected. To measure the occupancy, interviewees argue that the seasonality or number of opening days must be determined in the first step. In mountain regions, one-season hotels (i.e., opening term from November to April) are prominent in the German and Austrian hotel industry. However, in urban regions hotels typically operate throughout the entire year. Although several scholars found a low correlation between occupancy and energy consumption (AlFaris et al., 2016; Lai, 2016; Lanka Udawatta et al., 2010; Warnken et al., 2004), all interviewees state to collect the number of guests and rooms sold to benchmark resource consumption. When inquired about the significance of hotel chain affiliation in relation to resource consumption, the general consensus indicates that chain affiliation is not considered a determining factor. Similar to the findings of Iddawala et al. (2024), IR4 added that operators might get more support from brand headquarters on how to collect environmental figures but still have to work

[23] The star rating of the Hotelstars Union is a uniformed classification system across the European Union and offers guests a reliable orientation aid regarding quality level of accommodation offers. The classification criteria are based on current market observations and reflect guest expectations in the respective category. The rating into a star class is made by an independent commission. Regular inspections and self-monitoring ensure quality. Executive body in Austria is the Chamber of Commerce, in Germany the German Hotel Association (DEHOGA) (Hotelstars Union, 2020)

with the existing property, which might be inefficient. This result justifies the limited previous consideration in resource consumption benchmarking studies (Deyà Tortella and Tirado, 2011). Furthermore, IR14 highlights that environmental efforts are mostly related to the owner of the building rather than the operator. This is mainly caused by the regulatory pressure of EU Taxonomy for institutional real estate investors as well as the overall sustainability strategy of a company. As a result, according to the respondents, the following variables are essential within the operational characteristics of a hotel and resource consumption benchmarking:

Minimum Criteria

- Quality Level (according to Hotelstars Union 1-5 star)
- Seasonality / Opening days
- Type of board (No F&B Service / Breakfast only / Full Service)
- Operational concept
  - Main: City / Countryside
  - Focus: Wellness / Conference
- Number of guest nights/number of occupied rooms/occupancy level (guests/rooms/covers)

Optional Criteria

- Number and kind of outlets
- Number of employees
- Chain affiliation (yes/no)

5.2.6.2. Physical Factors

Physical factors are related to the real estate's structural attributes and build characteristics. Likewise to different academic publications (Bohdanowicz and Martinac, 2007; Tang et al., 2016; Xuchao et al., 2010), SUE and PO/L respondents argue that indoor floor area is the most important physical factor. IR16 (PO/L) highlighted that only floor area used for operational purposes[24] should be integrated within this variable. Respondents working within a hotel's day-to-day business are likelier to measure rooms or beds in the rooms area and seating spaces within the restaurant/conference area. Generally speaking, a splitting according to hotel outlets is recommended. There, different outlets were stated, but there was consensus that, as a minimum, a splitting in rooms and F&B must occur.

[24] Especially in rural areas other floor area (e.g., owner housing, other housing, farm, animal enclosures) which are not attributed to the hotel are existent and must therefore be excluded from calculations.

Another important measure, especially for installing hardware, is the historic protection of buildings. Especially in Germany and Austria, some hotels are located within historic buildings and thus are limited to hardware improvements. With respect to building age, respondents expressed divergent views. On one hand, age is not considered a reliable indicator of a building's overall condition, as hotels are subject to ongoing maintenance and continuous improvements. However, interviews agree on the findings of Wang (2012) that renovation steps are not easy to measure and that newly constructed hotels are generally more efficient and possess the technology to decrease resource consumption (e.g., smart meters, efficient HVAC systems, building materials). On the other hand, IR16 (PO/L) argues that not age-related factors but the scale of the energy certificate ("Energieausweis") should be the basis for energy efficiency. Nevertheless, the building year or, according to IR14 the last major refurbishment date, should be measured within the essential characteristics of a hotel to display the general built epoch. There, different clusters are recommended to group hotels accordingly (e.g., 50 years cluster). Nevertheless, the general building condition cannot be validated with the property's age. Other more granular hardware differentiation identified by respondents (e.g., wall insulation, the existence of bathtub, HVAC characteristics, number of floors) are excluded as measurement comparability, and data availability is limited. While age factors do affect energy, water, and subsequently, GHG emissions, respondents agree that waste consumption is not dependent on the property's building year.

With regards to relevance of laundry outsourcing, only three academic studies have recognized whether there are outsourced facilities in the hotel (Hu et al., 2015; Bohdanowicz and Martinac, 2007; Filimonau et al., 2011). Interviewees agree that the integration of an outsourced laundry service should be considered when calculating environmental intensity indicators. This is mainly important for energy and water figures, as external laundry facilities that small hotels (less than ten rooms) in the countryside mostly have their laundry in-house, and larger hotels and hotels within urban areas have all their laundry activities outsourced. There is consensus that the outsourcing departments must be asked within the hotel's general characteristics and strictly split when benchmarking environmental data. When resource figures (e.g., total water and energy consumption) of the external laundry are present, it may be added to compare with hotels that have their laundry in-house. This result aligns with the industry methodology HWMI, which encourages the display of water consumption in the outsourced laundry facilities (Sustainable Hospitality Alliance, 2020). As a result, the degree of outsourcing needs to be accounted for efficient environmental benchmarking.

As a result, the following variables are essential for benchmarking the physical characteristics of a hotel and resource consumption. The assumption is that when hotels are split according to the critical differentiations described below, hotels with similar characteristics are grouped, and hence, a valid benchmarking set is created:

Minimum criteria

- Operational used indoor floor area
    - preferably split by public and rooms area
- Number of rooms / beds
    - below 50 rooms
    - 50 – 100 rooms
    - 100 – 200 rooms
    - above 200 rooms
- Laundry outsourced (yes / no)

Optional criteria

- Number of seats in the restaurant
- Floor area of each outlet/zoning
- Age of the property clustering, e.g., > 1970; < 1970
- Historic preservation (yes/no)

5.2.6.3. External Factors

The third category – external factors – is generally associated with factors unrelated to the real estate or the hotel's operation. The first identified aspect is location and climate, where previous studies comparing different geographical locations performed weather normalization measures (Cabello Eras et al., 2016; Xin et al., 2012). With regards to the German and Austrian hotel industry, interviewees emphasize that climate is not a significant factor and that climatic differences across the countries are nearly non-existent in a peer group. Furthermore, with regards to the previously stated physical and operational factors it is argued that, one would only benchmark with other hotels with a similar size and concept, which generally is associated also with the geographical location and opening hours (i.e., a hotel mountains would not benchmark with a city hotel). Last but not least, weather normalization models are unreliable, and no uniform system exists. In water consumption, the weather has only an influence when large outdoor areas and gardening exist. This finding is contradictory to studies in other geographical regions, concluding that weather has a significant impact on resource consumption (Lai, 2015; Priyadarsini et al., 2009). In addition, if climate is recognized, the valid comparison of weather data is complicated due to missing climate-related factors and other dependent variables. These findings generally complement the study of Cabello Eras et al. (2016) and Xuchao et al. (2010) highlighting the complexity of weather normalization. Another identified external factor is the guest's behavior and geographical origin. Whereas the latter can be clustered by guest nationalities (e.g., relative share national guests, relative share international/EU guests), it is questionable whether any meaningful relationship about resource consumption differences can be built. All respondents agree that guest behavior cannot be generalized or clustered and remains, therefore, an unknown variable for resource consumption benchmarking.

5.3. Discussion and Conclusion Qualitative Research Stage

A thorough triangulation of the identified input and reference variables, grounded in both empirical analysis and insights from the literature review, has guided the formulation of a comprehensive indicator set. This framework specifies recommended resource input, reference units, appropriate reporting frequencies, and relevant hotel characteristics. Subsequently, the previously outlined research hypotheses are methodically revisited and evaluated in relation to the study's findings.

5.3.1. Final Set of Intensity Indicators

Energy Intensity Metrics

To accurately capture the total energy consumption, it is essential to include both purchased and self-generated ("internal") energy sources. As a result, the formula to calculate the total energy consumption (Q_T) of the study of Sheng et al. (2018) should be extended as follows to integrate self-generated ("internal") energy. This extended approach ensures a more comprehensive representation of the energy inputs used within the system.

Given $$\boldsymbol{Q_T = Q_E + Q_I - Q_f}$$

where $$Q_E = Q_e + Q_c + Q_s + Q_h + Q_d + Q_g + Q_n$$

the total energy consumption is defined as[25]

[25] Though, it has to be acknowledged that this energy consumption equation does not fully comply with the ESRS regulation. However, data needed (e.g., proportion of nuclear energy) is currently not possible to display from smart metering or the invoicing of energy contracts.

$$\underbrace{Q_T = Q_e + Q_c + Q_s + Q_h + Q_d + Q_g + Q_n}_{\text{External sourced energy } (Q_E)} + Q_I - Q_f$$

Q_T: Total Energy consumption	*Q_h: hot water*
Q_E: External sourced energy	*Q_s: steam*
Q_I: Internal sourced energy	*Q_d: diesel oil*
Q_f: Fed in renewable energy	*Q_g: gasoline*
Q_e: electricity	*Q_n: natural*
Q_c: chilled water	

To display the share of Qo and renewable energy (Qr) a splitting is recommended:

Total Energy Consumption (Q_T):	100%
Thereof external energy (Q_E):	x%
Thereof own produced energy (Q_O)	x%
Thereof non-renewable (Q_{nr}):	x%
Thereof renewable (Q_r):	x%

This leads to the formulation of the following intensity metrics to collect and benchmark energy consumption in the German and Austrian hotel industry. Due to decent data availability, the preferable disaggregation includes differentiation by energy source, considering both type and origin, to enable more accurate assessments. Further distinction by functional area, specifically between guest rooms and other operational spaces, enhances the precision of resource consumption analysis.

$$Energy\ use\ intensity\ (EUI) = \frac{total\ primary\ energy\ consumption\ in\ kWh}{total\ floor\ area\ (in\ m2)} \text{ per year}$$

$$Energy\ use\ per\ guest\ night\ (EUPGN) = \frac{total\ primary\ energy\ consumption\ in\ kWh}{total\ guest\ nights} \text{ per year}$$

$$Energy\ use\ per\ net\ revenue\ (EUPR) = \frac{total\ primary\ energy\ consumption\ in\ kWh}{total\ net\ revenue} \text{ per year}$$

Water Intensity Metrics

With regard to water resource input, it is essential to prioritize the measurement and benchmarking of external water withdrawal (A_E). When internal water sources (A_I) exist, a metering device should be added to gain total water consumption (A_T).

$$A_T = A_E + A_I$$

A_T: Total Water consumption
A_E: External sourced water
A_I: Internal sourced water

Total Water Consumption (A_T):	100%
Thereof external water (A_E):	x%
Thereof internal water (A_I)	x%
Thereof recycled (A_r):	x%
Thereof non-recycled (A_{nr}):	x%

This forms the basis for the development of the following intensity metrics, designed to support the collection and benchmarking of water consumption within the German and Austrian hotel industry.

$$Water\ use\ per\ guest\ night\ (WUGN) = \frac{total\ water\ consumption\ in\ liter}{total\ guest\ nights}\ \text{per year}$$

$$Water\ use\ per\ net\ revenue\ (WUR) = \frac{total\ water\ consumption\ in\ liter}{total\ net\ revenue}\ \text{per year}$$

Waste Intensity Metrics

When comparing academic studies with the findings from the qualitative phase, the limited analysis of waste and benchmark figures in the hotel industry can be attributed to several factors. First, measuring waste is time and resource-consuming. Second, there is no uniform waste management and measuring system across the European Union. Third, waste consumption is strongly related to the supply chain and national health regulations. Fourth, extensive training of all stakeholders involved is necessary to reduce waste consumption. Finally, a comprehensive waste benchmarking tool is necessary to compare waste figures nationally and internationally. As highlighted in Chapter 5.2.5.3, waste management is strongly related to local waste collection regulations.

Waste Type		Austria				Germany			
		Vienna	Graz	Lech	Schladming	Munich	Berlin	Sylt	Tegernsee
Non-hazardous	Residual	x	x	x	x	x	x	x	x
	Glass	x	x	x	x	x	x		x
	Paper	x*	x*	x*	x*	x*	x*	x*	x*
	Cardboard	x*	x*	x*	x*	x*	x*	x*	x*
	Metal	x**	x	x**	x**	x**		x**	x**
	Plastic	x**	x**	x**	x**				
	Food	x	x	x	x	x	x	x	x
Hazardous	Oil	x	x	x	x	x	x	x	x
	Other	x	x	x	x	x	x	x	x

*blue shading refers to a combined treatment of these waste types

** packaging recycling, together with plastic bottles

Table 26: Waste Input Variables German and Austrian Cities/Municipalities
Source: Author's own data

Therefore, an indicative comparison of waste separation management of different cities/municipalities is displayed in Table 26. As illustrated above, recycling and disposal schemes are different and, therefore, incompatible with a uniform waste management system and ESRS regulations. Furthermore, not all waste types listed are collected directly at the premise; some (predominantly hazardous waste) must be disposed of at designated locations outside the premise. Due to the inherent difficulties in distinguishing different types of waste and attaining consistency and considering ESRS E5-5 resource outflow regulations, it is recommended to reduce waste splitting for benchmarking resource consumption to organic (W_O), non-hazardous (W_{NH}) and hazardous waste (W_H). Furthermore, radioactive waste needs to be displayed separately to comply with ESRS E5-5. Therefore, the following equation can be formulated:

Given $$\boldsymbol{W_T = W_O + W_{NH} + W_H + W_{RA}}$$

where $$W_O = W_f + W_o$$

and $$W_{NH} = W_r + W_g + W_p + W_c + W_m + W_p$$

the total waste consumption is defined as

$$W_T = W_f + W_o + W_r + W_g + W_p + W_c + W_m + W_p + W_H + W_{RA}$$

Total Waste Consumption (W_T):	100%
Thereof reycycled (W_R):	x%
Thereof non-recycled (W_{NR})	x%

W_T: *Total Waste consumption*	W_r: *Residual waste*
W_{NH}: *Non-hazardous waste*	W_g: *Glass Waste*
W_H: *Hazardous waste*	W_p: *Paper waste*
W_{RA}: *Radioactive waste*	W_c: *Cardboard waste*
W_O: *Organic waste*	W_m: *Metal waste*
W_f: *Food waste*	W_p: *Plastic waste*
W_o: *Oil waste*	

When waste is only measured per container, it is recommended that the filling grade on premise be inspected each week and documented in a waste system before garbage collection to reliably aggregate numbers. Therefore, the following intensity metrics for waste related resource consumption reporting can be identified:

$$Residual\ waste\ in\ kg\ per\ guest\ night\ (WkgPGN) = \frac{residual\ waste\ generated\ in\ kg}{guest\ nights} \text{ per year}$$

$$Organic\ waste\ in\ kg\ per\ cover\ \ (WOkgPC) = \frac{organic\ waste\ generated\ in\ kg}{total\ covers} \text{ per year}$$

$$Residual\ waste\ in\ kg\ per\ net\ revenue\ \ (WkgPR) = \frac{residual\ waste\ generated\ in\ kg}{guest\ nights} \text{ per year}$$

GHG Emissions Intensity Metrics

Within GHG reporting, the common regulations of the Greenhouse Gas Protocol with Scope 1, Scope 2, and Scope 3 displayed in CO_2 equivalent ($kgCO_2e$) are most valid as a reporting unit within all stakeholder groups. This is in line with academic studies measuring GHG consumption (Filimonau et al., 2021; Huang et al., 2015; Tsai et al., 2014) as well as industry-specific measuring tools such as the Hotel Carbon Measurement Initiative (Sustainable Hospitality Alliance, 2022b). When reporting units, such as those on invoices, are not standardized, it is advisable to recalculate using the units specified above. Similar to the study of Filimonau et al. (2011) and Hu et al. (2015) interviewees highlight that boundaries are necessary for collecting Scope 3 emissions. As a result, Figure 19 illustrates an adapted GHG emissions flow diagram for the hotel industry illustrating feasible streams has been developed from existing regulative frameworks

(Sustainable Hospitality Alliance, 2022a), academic literature (Filimonau et al., 2011; Ronning and Brekke, 2009), and the qualitative data conducted from the semi-structured interviews.

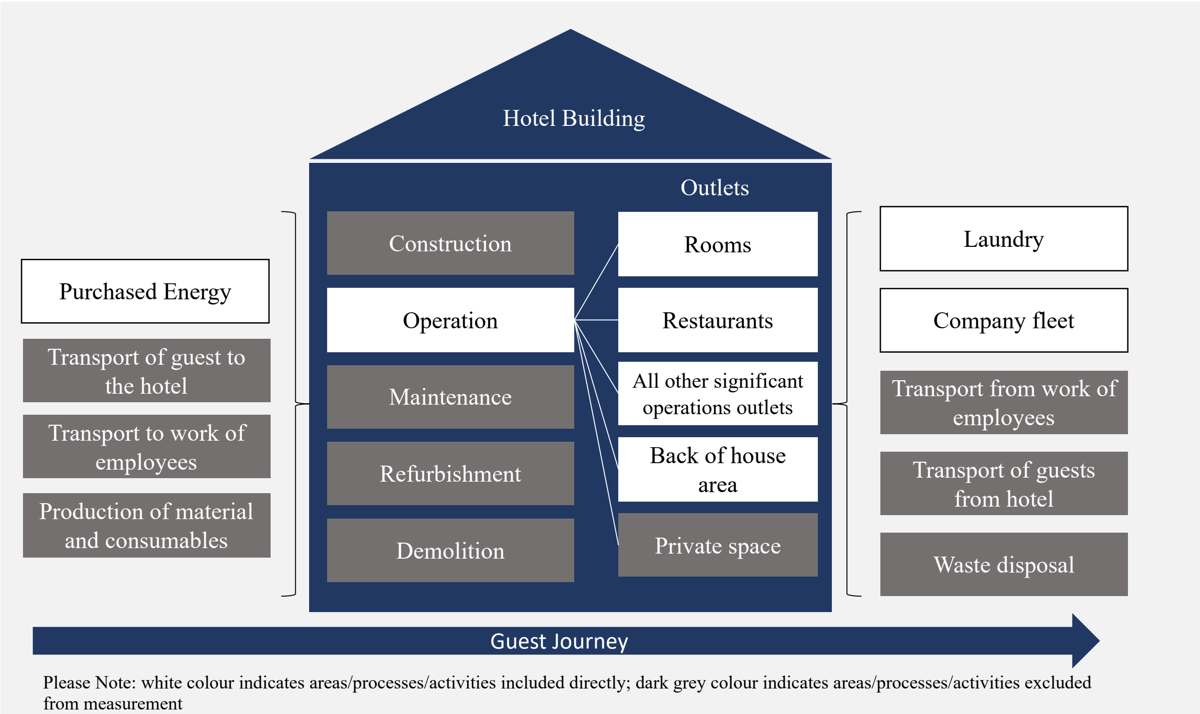

Figure 19: GHG Measurement System Boundaries in Hotel Operations
Source: Author's own data

Despite the inherent challenges, the initial focus in the German and Austrian hotel industry is on collecting and benchmarking Scope 1 and Scope 2 GHG emissions, as they are the most feasible to measure and standardize. Challenges such as data availability, reporting inconsistencies, and varying measurement standards complicate comprehensive emissions tracking. Establishing a benchmarking framework for these emissions lays the foundation for expanding the assessment to Scope 3 emissions, which involve more complex and indirect sources. As a result, the following intensity metrics are identified:

$$Carbon\ emission\ Scope\ 1 + 2\ per\ guest\ night\ (COPGN)\ = \frac{kg\ CO2{-}e}{guest\ nights}\ \text{per year}$$

$$Carbon\ emission\ Scope\ 1 + 2\ use\ intensity\ (COUI)\ = \frac{kg\ CO2{-}e}{floor\ area}\ \text{per year}$$

$$Carbon\ emission\ Scope\ 1 + 2\ per\ net\ revenue\ (COPR)\ = \frac{kg\ CO2{-}e}{total\ net\ revenue}\ \text{per year}$$

5.3.2. Determinants of Resource Consumption

Table 27 summarize the findings and illustrate the different hotel characteristics and the expected sign over total resource consumption. The analysis highlights that operational and physical factors play a dominant role in driving resource consumption, while external factors show more variability. Larger properties, higher occupancy rates, and expanded services consistently lead to increased consumption, whereas resource-saving measures are the only factor that reduces usage. Certain variables, such as chain affiliation, location, and building characteristics, lack a clear consensus, indicating their impact varies based on context. Notably, outsourcing laundry significantly increases resource use, while guest behavior remains unexplored, highlighting a gap in current research.

Independent Variables		Expected Relationship with Total Resource Consumption			
		Energy	Water	Waste	GHG
Group	Determinants				
Operational Factors	Quality Level	Significant	Significant	Significant	Significant
	Number and Kind of Outlets	Positive	Positive	Positive	Positive
	Occupancy Level	Positive	Positive	Positive	Positive
	No. of Guests	Positive	Positive	Positive	Positive
	Seasonality / Opening days	Significant	Significant	Significant	Significant
	Type of Board	Significant	Significant	Significant	Significant
	Operational Concept	Significant	Significant	Significant	Significant
	Nr. of Employees	Positive	Positive	Positive	Positive
	Chain Affiliation	No consensus	No consensus	No consensus	No consensus
	Resource-saving Measures	Negative	Negative	Negative	Negative
Physical Factors	Building Size (GFA)	Positive	Positive	Positive	Positive
	Number of Rooms / Beds	Positive	Positive	Positive	Positive
	Number of Seats in Restaurant	Positive	Positive	Positive	Positive
	Age of Building	No consensus	No consensus	No consensus	No consensus
	Historic Preservation	No consensus	No consensus	No consensus	No consensus
External Factors	Location	No consensus	No consensus	No consensus	No consensus
	Climate / Temperature	Non-significant	Non-significant	Non-significant	Non-significant
	Laundry outsourced	Significant	Significant	No consensus	No consensus
	Guest Behaviour	Unexplored	Unexplored	Unexplored	Unexplored

Positive: *resource consumption increases*
Negative: *resource consumption decreases*
Significant: *a correlation is predicted*
Non-significant: *no correlation is predicted*
No consensus: *there is no consensus among the interviewees*
Unexplored: *not explored due to complexity*

Table 27: Expected Sign over Total Resource Consumption
Source: Author's own data

Furthermore, the findings on intensity-based resource consumption, measured per floor area for energy consumption, guest night for water consumption, and per guest for waste consumption and GHG emissions, are presented in Table 28. Compared to the previous table on total resource consumption, significant differences emerge, particularly in operational and physical factors. While total resource consumption shows a positive correlation between hotel size and resource use, intensity-based metrics reveal efficiency gains, where larger hotels and higher occupancy levels reduce per-unit consumption. This is evident in negative relationships for occupancy level, number of guests, building size, and number of rooms/beds, indicating that while larger properties consume more resources overall, they do so more efficiently on a per-guest basis. In contrast, quality level, type of board, and operational concept remain significant drivers of intensity-based consumption. Similarly, resource-saving measures consistently reduce resource intensity, reaffirming their effectiveness across different consumption types. External factors exhibit less influence in this analysis, with location, climate, and outsourced laundry showing no consensus or non-significant effects, contrasting with their stronger impact on total consumption. The most notable gap remains within the external factor guest behavior, which remains unexplored.

Independent Variables		Expected Correlation Between Intensity Variables and Consumption			
Group	Determinants	Energy	Water	Waste	GHG
	Dominant Variable	per Floor Area	per Guest Night	per Guest	per Guest Night
Operational Factors	Quality Level	Significant	Significant	Significant	Significant
	Number and Kind of Outlets	Positive	Positive	Positive	Positive
	Occupancy Level	Significant	Non-significant	Non-significant	Significant
	No. of Guests	Significant	Non-significant	Non-significant	Significant
	Seasonality / Opening days	Significant	Non-significant	Non-significant	Significant
	Type of Board	Significant	Significant	Significant	Significant
	Operational Concept	Significant	Significant	Significant	Significant
	Nr. of Employees	Positive	Positive	Positive	Positive
	Chain Affiliation	No consensus	No consensus	No consensus	No consensus
	Resource-saving Measures	Negative	Negative	Negative	Negative
Physical Factors	Building Size (GFA)	Negative	Negative	Negative	Negative
	Number of Rooms / Beds	Negative	Negative	Negative	Negative
	Number of Seats in Restaurant	No consensus	No consensus	No consensus	No consensus
	Age of Building	Significant	No consensus	Non-significant	No consensus
	Historic Preservation	No consensus	No consensus	Non-significant	No consensus
External Factors	Location	No consensus	No consensus	No consensus	No consensus
	Climate / Temperature	Non-significant	Non-significant	Non-significant	Non-significant
	Laundry outsourced	Significant	No consensus	Nin-significant	No consensus
	Guest Behaviour	Unexplored	Unexplored	Unexplored	Unexplored

Positive: *resource consumption increases*
Negative: *resource consumption decreases*
Significant: *a correlation is predicted*
Non-significant: *no correlation is predicted*
No consensus: *there is no consensus among the interviewees*
Unexplored: *not explored due to complexity*

Table 28: Expected Sign over Resource Consumption using Intensity Metrics
Source: Author's own data

5.3.3. Findings in Relation to Core Qualitative Hypotheses

The conclusion of the decoded qualitative data is presented through the process of addressing the hypotheses outlined in the methodology section.

Hypothesis 1:

H_0: In the context of environmental reporting, it is hypothesized that energy consumption, water usage, waste generation, and GHG emissions figures are perceived as critical metrics, forming the cornerstone of sustainability and corporate responsibility for the German and Austrian hotel industry.

While the hypothesis finds general support, knowledge of EGWW benchmarking varies, and additional aspects emerge from the analysis. Although EGWW measurements represent essential components, energy and water are measured more frequently than waste and GHG emissions. In the context of GHG measurement, the German and Austrian hotel industry remains in an early stage of development, resulting in limited familiarity with GHG calculation methods. However, larger and chain-affiliated hotels have better action plans for environmental measuring than smaller, privately owned hotels. Interviewees highlight that environmental measuring is interconnected and must be considered within social and governance aspects, e.g., in the training of stakeholders (e.g., employees, management suppliers) and rigorous auditing of results.

Hypothesis 2:

H_0: Stakeholders in the German and Austrian hotel industry have a high level of awareness of the EU Taxonomy and its associated reporting obligations (CSRD, ESRS).

This hypothesis is rejected, as the industry overall demonstrates low awareness of the EU Taxonomy legislation and its reporting requirements. This lack of awareness is largely attributed to the highly fragmented nature of the industry, where approximately 80% consists of family-owned SMEs that often lack the resources or expertise to navigate regulatory frameworks. While larger international hotel chains and real estate owners are aware of the regulations, uncertainty remains regarding specific reporting obligations. This is exemplified by the inconsistent ESG reporting practices observed among major hotel groups such as Marriott International, Hilton Worldwide, and Accor. Additionally, the absence of sector-specific standardized intensity metrics within the ESRS framework further exacerbates reporting inconsistencies across the industry.

Hypothesis 3:

H_0: Intensity metrics measuring factors related to EGWW are consistently and uniformly identified and applied across the German and Austrian hotel industry.

This hypothesis is rejected. Similar to the previous academic studies, interviewees agree that the hotel industry needs distinct intensity metrics for the operational needs of the hotel industry. Furthermore, it is emphasized that resource input and tailored reference units are necessary to generate valid intensity metrics. Nevertheless, as elaborated in Hypotheses 2 current reporting frameworks are highly inconsistent, and ESRS does not provide specific intensity metrics for benchmarking. International hotel companies report on EGWW on different granularity levels. Within the German and Austrian hotel industry, no conformity is present. Interviewees conclude that an easy-to-use framework is necessary that displays intensity metrics and allows benchmarking externally according to specific characteristics of the hotel.

Hypothesis 4:

H_0: The data required to construct intensity metrics, particularly in the context of day-to-day hotel property operations, can be easily collected without significant resource or time constraints.

This hypothesis is partly supported. Depending on the granularity level of analysis, interviewees conclude that a basic set of intensity metrics can be created with existing data in the field of energy, water, and waste consumption. Calculating GHG emissions is more complex and demands an external service provider. However, intelligent sensors and interconnected HVAC hardware enhance environmental measuring. Furthermore, it is found that the coupling of data and implementation strategies is currently nonexistent, especially within the SME hotels in the German and Austrian area. Due to the separation between property ownership and operational responsibilities, as well as the contractual arrangements typically in place, access to environmental resource data is generally confined to the hotel operator rather than the owner. Existing lease agreements seldom contain provisions addressing environmental sustainability or the modernization of building infrastructure for environmental purposes. Consequently, obtaining data relevant to EU Taxonomy compliance necessitates direct engagement with the operator. Such negotiations are essential to ensure alignment with regulatory requirements and to facilitate the necessary documentation and reporting obligations.

Hypothesis 5:

H_0: The intensity metric used for benchmarking energy resource consumption in the German and Austrian hotel industry is the measurement of primary energy demand per square meter, expressed in kilowatt-hours (kWh).

This hypothesis is partly supported. Within input variables, the energy mix, i.e., the display of different energy sources, is essential. Furthermore, hotels must disclose their share of green energy as well as a share of their own produced energy. While the per-floor measurement is the basis for the "Energieausweis" and is most used for benchmarking purposes, the energy use per guest night is found to be similarly important as it integrates an occupancy-related variable. Both reference variables can be used in all types of hotel concepts and geographical locations. Furthermore, enhanced communication with the guest about the environmental footprint is possible when this metric is reported. To comply with EU Taxonomy (ESRS E1-5 Energy Intensity), the display of energy use per net revenue in million is recommended. kWh is found to be the dominant reporting unit of energy related consumption.

Hypothesis 6:

H_0: The intensity metric for benchmarking water resource consumption in the German and Austrian hotel industry is the assessment of total water consumption per occupied room, measured in liters.

This hypothesis is partly supported. Issues related to water scarcity, water recycling, and greywater measurement are neglected in the German and Austrian hotel industry. Current practices in this field involve measuring total water withdrawal. A splitting of internal and external water sources as well as recyclability share is preferred, depending on data availability. Contrary to energy consumption, where the floor-related variable was dominant, interviewees underline the strong dependency on the occupant level when measuring water consumption. Contrary to the existing literature and industry frameworks by measuring the occupied rooms, the number of total guests is found as the dominant reference unit. The primary reason is the better accuracy of results, ignoring the number of guests in the room. Additionally, to comply with ESRS E3-4, the water use per net revenue is recommended to be displayed. Reporting in liters is the preferred unit for documentation, as it provides a standardized and clear method for measuring volume, ensuring consistency and accuracy.

Hypothesis 7:

H_0: The dominant intensity metric to benchmark waste resources in the German and Austrian hotel industry is total waste per guest, measured in kg

This hypothesis is partly supported. While the intensity metric is generally agreed upon, the input variables are inconsistent throughout the German and Austrian hotel industry. This is mainly due to different weighting and waste-splitting systems. Due to missing direct measuring of waste figures, hotel management relies entirely on the statistics of the waste disposal companies. Therefore, values of waste splitting may be distorted, resulting in inaccurate data. It is found that food waste is predominantly produced in the F&B outlets and tracked throughout all hotels. Similar to other academic studies (Ball and Taleb, 2011; Debnath, 2015), favoring the guest as an reference variable is identified. There, interviewees highlight that the guest is the main contributor to waste generation. Similar to energy and water intensity metrics, it is advisable to calculate the total waste consumption per million units of net revenue. With regard to the reporting unit, an inconsistency has been identified. When waste is measured by weight, kilograms are the predominant unit; however, for non-weighted waste consumption (e.g., when billed based on container size), liters are the prevailing unit. This discrepancy prevents recalculation, leading to potential distortions in the reported values.

Hypothesis 8:

H_0: The intensity metric to benchmark GHG consumption in the German and Austrian hotel industry is carbon footprint per square meter, measured in $kgCO_2e$ and split in Scope 1,2 and 3

This hypothesis is partly supported. While calculation tools and reporting schemes exist for the hotel industry, the application and resulting relevant data are still missing throughout the German and Austrian hotel industry. Regarding input variables, Scope 1 and 2 are generally manageable to calculate. Parts of Scope 3 emissions are still not measured thoroughly, as clear boundaries do not exist, and challenges related to double-accounting GHG emissions are not clarified. A framework of what can be measured throughout a hotel property has been developed in this study. Furthermore, an external service provider (e.g., certification of the environmental label) is necessary to obtain GHG numbers, which hinder hotel management from measuring. Regarding reference variables, occupancy-related and per floor area factors are identified as dominant. To be compliant with CSRD reporting obligations, carbon emission Scope 1 and 2 per million units of net revenue must be displayed (ESRS E1-6 Gross GHG emissions intensity).

Hypothesis 9:

H_0: Non-financial sustainability reporting is typically conducted on an annual basis, aligning with financial reporting obligations in most regulatory frameworks.

Although this hypothesis is generally supported, it is discovered that the reporting frequency varies depending on the kind of measurement, reporting reason, and the property hardware installed. Due to data availability, energy and water measurements can be done more often than GHG measurements. For operational use and creating awareness (e.g., training employees) reporting frequency is more frequent than for EU Taxonomy reporting obligations. Furthermore, while analog measuring generally hinders frequent measurements, smart metering connected with an online dashboard increases application and integration in the day-to-day business. To attain uniformity, a reporting frequency per year is recommended as a starting point.

Hypothesis 10:

H_0: Hotels in Germany and Austria are more inclined to utilize external benchmarking as opposed to internal benchmarking when assessing and measuring environmental factors.

This hypothesis is rejected. While previous academic studies in the field of EGWW are predominantly benchmarking against other hotels, hotels in Germany and Austria are still collecting and measuring with absolute figures and performing internal benchmarking. Thus, absolute figures limit internal and external comparability. This is partly due to the highly fragmented industry being 80% SMEs and privately owned and operated. Chain-affiliated hotels generally may compare inter-group data.

Hypothesis 11:

H_0: To establish a valid peer group for clustering, it is necessary to differentiate and categorize entities based on both their physical attributes and operational characteristics.

This hypothesis is supported. Generally, it is found that physical and operational characteristics must be split to generate a valid peer group. Nevertheless, the granularity level of splitting must be taken into account. Furthermore, external factors such as climate and guest behavior are discussed. While the interviewees diminish the relevance of climatic conditions, researching room occupants' attitudes is evaluated as promising. However, due to the multitude of factors affecting guest behavior and missing data, this factor remains unexplored and should be investigated in future research. Furthermore, resource-relevant outsourced departments such as external laundry must be considered. Nevertheless, generating appropriate divisions is always depending on data availability. Therefore, a reporting matrix with minimum criteria is implemented to achieve a valid splitting while maintaining a minimal level of granularity. Elements are related to the size of the building (number of rooms or GFA in m^2), quality of service (star rating) as well as occupancy level of the hotel building (occupied guests). These essential characteristics can be applied to all parts of measuring environmental data. Depending on the kind of hotel and managerial needs, further splitting illustrated in Table 27 and Table 28 may be integrated. Ultimately, interlinked smart sensors with an online dashboard showing intensity metrics and a valid peer group can be created with this approach and should be implemented throughout the German and Austrian hotel industry.

6. Quantitative Research Stage

The quantitative stage builds upon insights from the literature review and qualitative research phase. This chapter follows the outlined quantitative research methodology, detailing the selected variables and data-cleaning process. The findings are then presented through descriptive and inferential statistical analyses applied to the dataset.

6.1. Quantitative Research Process

The aim is to apply the defined intensity metric framework (see Chapter 5.3.1) to a quantitative data set and provide more detailed statements about dependent and independent variables of resource consumption in the hotel industry. Distinct characteristics and resource consumption parameters are necessary to create a valid statistical model. As highlighted by different scholars and within the qualitative interviews, data collection via a predetermined questionnaire is time-consuming, and access to data is limited, especially within the highly fragmented German and Austrian hotel industry. Therefore, an industry partner dealing with ESG certifications for hotels provided access to their database, and an existing dataset is used as the basis for this research.

Therefore, the research process is as follows: First, grouping into clusters is executed to separate hotels' operational concepts. The characteristics are summarized descriptively and visually. Second, mean, median, and standard deviation analyses are performed out of this group. Frequency and proportions are visually displayed with box plots and pie charts. In the third step, bivariate correlation analysis is performed in inferential statistics. Multiple correlation models identify the determinants of energy and water intensities to create comparable benchmarking sets ultimately. Fourth, a model integrating grouped variables and identifying their interactions is developed. Finally, deriving from descriptive statistics and inferential analysis, only statistically significant variables are included in three linear regression models to predict total energy and water consumption. Likewise to other studies within this field (Becken et al., 2001; Bohdanowicz and Martinac, 2007; Deng, 2003), a regression coefficient of $R^2 > 0.6$ and more is treated as a potential indicator, $R^2 > 0.8$ treated as potential solid indicator.

The selection of statistical methods is guided by the nature of the data set and the specific research objectives of each hypothesis. Correlation analysis is employed to identify relationships between variables without implying causality, making it particularly useful for exploring associations between resource consumption metrics, such as energy and water usage, and hotel characteristics (e.g., Hypotheses 12 – 22). ANOVA is then applied to compare mean differences across multiple groups, such as hotel service types and locations, to assess their impact on sustainability outcomes (Hypotheses 25). Finally, regression analysis is utilized to examine more complex relationships between continuous variables, allowing for predictive modeling and a deeper understanding of how multiple factors influence resource consumption patterns (Hypotheses 23 – 24). In conclusion, Table 29 displays the descriptive and inferential methods employed to analyze the defined hypotheses in Chapter 4.2.2:

Statistical Method	Hypothesis Number
Mean and median comparison, as well as standard deviation	serve as the foundation for analyzing all hypotheses. Additional statistical methods are applied depending on the specific hypothesis.
Frequency and proportion value representation in diagrams, pie charts and box plots	
Normality analysis (*Shapiro-Wilk* and *Kolmogorov-Smirnov Test*)	serve as the foundation for inferential statistics
Correlation analysis (*Spearman Rho* and *Rank Biserial Test*)	Hypothesis 12 – Hypothesis H22, Hypothesis 26
Group comparison analysis (*ANOVA*)	Hypothesis 25
Regression plots	Hypothesis 23, Hypothesis 24
Multiple linear regression analysis	Hypothesis 23, Hypothesis 24

Table 29: Statistical Methods used for Hypotheses
Source: Author's own work

6.1.1. Database Origin

This research uses data from the GreenSign certification scheme. Since 2014, GreenSign has acted as a market leader in the German and Austrian hotel industry for ESG hotel certification. The holistic criteria catalog is based on transnational frameworks such as ISO 14001 (see Chapter 3.3.1) and EMAS (see Chapter 3.2.1). Since 2022, the certification catalog has been certified by the GSTC sustainability standards (see Chapter 3.2.3), assuring highest quality standards. The criteria catalogue is suitable for individual hotels as well as hotel groups, and is based on 100 different aspects within eight core areas. A score can be reached for each element, resulting in a total sustainability performance clustered in levels (Level 1 being the lowest up to 20% of the total score, Level 5 being the highest over 90% of the total score). The certification process consists of three key steps: the submission of an application (Step 1), the tool insertion process and self-evaluation (Step 2), and the issuance of certification (Step 3). Quality assurance takes place with an external audit of the submitted data. Despite the hotel sustainability certification, GreenSign offers products for Gastronomy, SPA and Office assets. The headquarters is based in Berlin, Germany. With regards to the calculation of GHG emissions, GreenSign cooperates with myclimate.org (GreenSign, 2023). In conclusion, GreenSign represents the leading provider of ESG certification within the German-speaking hotel industry. Its certification process is grounded in internationally recognized transnational frameworks, ensuring methodological rigor and relevance. Furthermore, all data entries undergo external auditing, thereby enhancing the credibility, validity, and overall quality of the reported information.

6.1.2. Variables used

GreenSign provided vital variables relating to hotels' energy, water, and waste consumption from their benchmarking database. The necessary critical variables are extracted from the literature review and the qualitative part of this dissertation. To complement the database and support the anticipated benchmarking model, missing data[26] were supplemented using publicly available sources, such as official hotel websites and online platforms (e.g., www.booking.com or www.hotel.de). Despite categorical variables, which can take any number within a specific range (e.g., kWh of energy consumption), dichotomous variables were created. These variables are categorically ordered, where 1 means the presence of a facility (e.g., wellness area, the existence of an official ESG document) and 0 represents the absence (Hosmer et al., 2013).

As noted in previous studies, the variables and quantitative analysis possibilities are strongly related to the available data (Antonova et al., 2023; Bohdanowicz and Martinac, 2007). Therefore, despite the generated variable set from the qualitative interviews, it has to be acknowledged that not all variables generated from the interviews within the qualitative part of this dissertation are present in the quantitative research data set. The following attributes are recognized and extrapolated from the qualitative findings (see 5.3.1), and a detailed comparison with the existing quantitative data set from GreenSign is displayed in Table 30.

[26] added information from additional sources: Chain affiliation, building year, building year (cluster <2018 and >2018, <1950, between 1950 and 2000, >2000), number of opening days, seasonality, number of floors, number of rooms, number of beds, operational concept/type of accommodation, air-conditioning, wellness focus, wellness area small/large, MICE focus, type of F&B board (no F&B, breakfast only, half-board, full-board), number of restaurants, location (mountain, seaside, city, countryside).

Category	Identified Factor	Explanation	Included in Data Set
Resource Data	Energy Consumption 1	Total Energy Consumption, per Energy source	
	Energy Consumption 2	% of green energy	partly
	Energy Consumption 3	% of own produced energy	partly
	Water Consumption 1	Total Water Consumption	
	Water Consumption 2	thereof recycled water in %	
	Waste 1	Total waste	partly
	Waste 2	split by waste type (e.g. Food Waste, Residual Waste)	partly
	GHG emissions	GHG emissions split by Scope 1, 2 and 3	
Operational Factors	Quality Level	1 to 5 star	
	Number and kind of Outlets	No. of Restaurants, existence of wellness area, MICE area, Pools, Garden, Other	
	Occupancy Level	average occupancy of rooms	
	Total revenue	in EUR mio.	
	No. of guests / guest nights	Total guests in house / Total guest nights	
	No. Of Covers in F&B	Total covers in restaurant outlets	
	Seasonality / Opening days	Number of days open, if not full year, identify whether winter or summer	
	Type of board	No F&B / Breakfast / Half-Board / Full-Board	
	Operational concept	Business / Leisure / Other, Focus on Wellness or MICE	
	Number of employees	in FTE	
	Chain affiliation	yes / no	
Physical Factors	Building size (GFA)	in m2 used for hotel operations	
	Number of rooms		
	Number of beds		
	Number of seats in restaurant(s)		
	Age of building	when building hardware was completely renewed, year of renovation was taken	
	Historic preservation	yes / no	
External Factors	Location 1	Mountain / Seaside / City / Countryside	
	Location 2	Germany / Austria / Switzerland	
	Laundry outsourced	yes / no	

Green colour = included in the model; red colour = not included in the model

Table 30: Quantitative Variable Comparison with Qualitative Research Findings
Source: Author's own data

When analyzing the table, detailed information on resource consumption data becomes evident, particularly with regard to electricity and heating each displayed in kWh. Although neither absolute figures nor the relative share of self-produced energy are provided, the type of self-generated energy is indicated, for example through the presence of photovoltaic or solar systems. Furthermore, detailed operational energy efficiency practices (e.g., LED lamps, use of shading systems) and hardware energy efficiency (e.g., heat recovery of air, insulated cables) are evident. In the field of water consumption, all necessary variables are present. However, only direct water use is measured, ignoring grey or recycled water. Within waste consumption, no absolute figures of resource use are displayed. However, waste management operational practices are collected (e.g., tracking of waste consumption, existence of waste separation system) and displayed in the analysis section.

As highlighted by Kapferer and Breyner (2023) and respondents of the qualitative part, boundaries of GHG emission tracking are not standardized. Consequently, in the data set detailed GHG emissions data is currently unavailable and therefore excluded from analysis. Nevertheless, GHG compensation practices are displayed (e.g., compensation for corporate events, guest journey, and hotel stay in general). The operational variables are missing the total revenue, total covers in the restaurant(s), and the number of full-time equivalents (FTE). With regard to physical characteristics, information such as floor area, the number of restaurant seats, and historic preservation status is not available within the dataset. As a result, commonly used ratios such as EUI and WUI cannot be calculated. In line with previous research (Deng, 2003; Karagiorgas et al., 2007), this study therefore adopts a more user-centric approach by employing energy and water consumption metrics per occupied room (EUPOR, WUPOR) and per guest night (EUPGN, WUPGN). This result aligns with the qualitative interviews highlighting that most of the hotels do not possess floor area figures, hindering further analysis and reporting. The outsourcing degree of the laundry is collected in detail with a distance in km of washing provider to the hotel site.

As previously discussed, weather normalization is often done in building energy benchmarking so hotels in different geographical locations can be compared. However, most studies found an insignificant relationship (Huang et al., 2015), and there is still no consensus on whether weather normalization is reliable (Cabello Eras et al., 2016). In this study, weather normalization is not considered for the following reasons. Firstly, according to the qualitative interview respondents, climatic differences exist but are diminishable within the researched regions. This is further underlined by other studies conducted in a narrow geographical setting and performed no weather normalization (e.g., Xuchao et al., 2010 in Singapore) or concluded no significant evidence on resource consumption figures (e.g., (Huang et al., 2015). Second, prevailing weather normalization models are often criticized as unreliable (Akander et al., 2005) even in climatically similar regions (Kim and Oldham, 2017). Third, monthly consumption data is missing within the data set, limiting weather normalization possibilities. Within water consumption benchmarking, no evidence was found that weather plays a significant role (Antonova et al., 2023). Nevertheless, it has to be acknowledged that weather normalization should be reconsidered when adding additional research data from, e.g., Southern or Northern European countries.

Variable Abbreviation	Description
internal_number	Internal Number
hotel_name	Hotel name in database
post_code	Post code
location	Location/City
country	Country
federal_state	Federal State
star_rating	Star rating from 1 (budget) to 5 (luxury)
building_year	Building year of building (or major renovation)
opening_days	opening days
seasonality	opening times when not 365 days a year
nr_floors	Number of floors
nr_Rooms	Number of Rooms
nr_beds	Number of beds
operational_concept	Operations concept (Leisure, Business, Other)
wellness_size	Wellness Size
nr_MICE_rooms	Number of MICE rooms
nr_people_MICE	Number of people in MICE area
type_of_fb_board	Type of board (brekfast, half- or full-board, no F&B)
no_restaurants	Number of Restaurants
City_Countryside	Location (City, Countryside)
TTL_guestnights	Total guest nights
TTL_roomnights	Total room nights
av_occupancy	average occupancy level of rooms
av_adr	average rate in Euro
av_revpar	average revenue per available room (REVPAR)
TTL_electricity	total electricity consumption in kWh
electricity_per_gn	total electricity consumption in kWh per guest night
electricity_per_rn	total electricity consumption in kWh per room night
electricity_per_bed	total electricity consumption in kWh per bed per year
electricity_per_room	total electricity consumption in kWh per room per year
TTL_heating	total heating consumption in kWh
heating_per_gn	total heating consumption in kWh per guest night
heating_per_rn	total heating consumption in kWh per room night
heating_per_bed	total heating consumption in kWh per bed per year
heating_per_room	total heating consumption in kWh per room per year
TTL_energy	total energy consumption in kWh
energy_per_gn	total energy consumption in kWh per guest night
energy_per_rn	total energy consumption in kWh per room night
energy_per_bed	total energy consumption in kWh per bed per year
energy_per_room	total energy consumption in kWh per room per year
TTL_water_consumption	Total water consumption in liters
water_consumption_per_gn	Water consumption per guest night
water_consumption_per_rn	Water consumption per room night
water_consumption_per_bed	Water consumption per bed per year
water_consumption_per_room	Water consumption per room per year

Table 31: Categorial Variable Set
Source: Author's own data

The database originally comprised 215 variables, primarily focused on environmental aspects relevant to the research objectives. With additional data from secondary sources (see Chapter 6.1.2), the total number of variables expanded to 241. Rather than employing a traditional statistical reduction, the refinement process centered on restructuring the data for improved analytical clarity. Variables from the industry-oriented questionnaire were reorganized to align with SPSS requirements and enhance quantitative analysis. For example, rather than considering total annual energy consumption and guest numbers as separate metrics, energy consumption per guest is derived by dividing total consumption by the number of guest nights. Consequently, the final data set comprised 45 variables in numeric and non-numeric categorial entries and 103 variables limited to binary/dichotomous entry (0 = no or not existent, 1 = yes or existent). The variables and their descriptions with additional information are displayed in Table 31 and Table 32.

Variable Abbreviation	Description
buildingyear_<5years	building year >5 years
MICE	MICE area existent
wellness	Wellness area existent
air_Conditioning	Air conditioning existent yes /no
chain_Affiliation	Chain affiliation
ESG_document	existence of official ESG document for download
documentation_of_energy	documentation of energy consumption
documentation_of_energy_monthly	monthly documentation
documentation_of_energy_yearly	yearly documentation
certification_existent	The new building was built according to DGNB, LEED or a similar recognized building certification
low_energy_house	The new building is built according to sustainable aspects (e.g. low-energy house, energy-saving house)
energy_upgrade_of_the_building_hull	an energetic upgrade of the building envelope
energy-	an energy-efficient renovation indoors (e.g. doors, windows, walls)
roof_insulation	roof insulation (e.g. intermediate and/or over-rafter insulation, flat roof insulation)
cellar_insulation	basement insulation (e.g. on the heated or unheated side)
insulating_glazing	Insulating glazing with a low UV value (minimum requirement: UV $\leq$ 1.3 W/(m²K)
green_energy_75%	at least 75% in the electricity mix is from green sources
green_energy_100%	100% in the electricity mix is from green sources
own_energy_cogeneration_plant	Own energy is produced via combined heat and power plant (CHP)
own_energy_solar	Own energy is produced via solar energy (thermal)
own_energy_photovoltaic	Own energy is produced via photovoltaics
own_energy_water_energy	Own energy is produced via hydropower
own_energy_wind	Own energy is produced via wind energy
own_energy_bioenergy	Own energy is produced via bioenergy
own_heating_cogeneration_plant	Own heating via combined heat and power plant (CHP)
own_heating_heat_exchanger	Own heating via heat exchanger
own_heating_wood_pellets	Own heating via wood pellet or wood chip plant
own_heating_bio_gas	Own heating via bio gas
own_heating_district_heating	District heating from waste incineration
own_heating_waste_water	Central extraction from wastewater
own_heating_waste_water_not_centralised	Decentralized extraction from wastewater
automatic_switch-off_function_for_heating	Energy efficiency action: Automatic switch-off function for heating, ventilation when windows are open
LED_lamps	Energy efficiency action: Light sources with energy-saving lamps/LED lamps
low_energy_television	Energy efficiency action: Use of energy-saving televisions
shading_systems_jalousien	Energy efficiency action: Use of shading systems (e.g. curtains, blinds)
minibar_with_energy_efficiency_function	Energy efficiency action: Minibar with energy saving function (e.g. when not occupied)
no_minibar_in_room	Energy efficiency action: No minibar in the room
drinks/snack_machines	Energy efficiency action: Use of Maxibar(s) (drinks and/or snack machines)
no_coffee_machine_in_room	Energy efficiency action: No coffee machine and/or kettle in the room
no_reception_lighting	Energy efficiency action: No reception lighting when arriving in the room
information_booklet_for_guests_energy	Energy efficiency action: Information to raise guests' awareness of energy efficiency
HRMS_existent	Demand-oriented control of the HRMS with regard to room climate, light/power, sun protection (e.g. blinds)
HRMS_connected_to_reservation_system	HRMS is connected to the reservation system/front office system
HRMS_controlled_by_guest	HRMS is individualized and can be controlled by the guest in the room (e.g. power interruption via card holder or main switch)
insulated_cables_in_heating	Building energy efficiency: Insulated cables in the heating distributor
modern_condensing_boilers_with_heat_rec	Building energy efficiency: modern condensing boilers with heat recovery of exhaust gases and condensate
boilers_in_cascade_connection	Building energy efficiency: several boilers in cascade connection to optimally cushion fluctuating energy requirements
geothermal_heating_with_heat_pumb	Building energy efficiency: alternatively: geothermal probe heating with a heat pump
hot_water_with_heating_cascade	Building energy efficiency: Hot water preparation through heating cascade
hot_water_tanks	Building energy efficiency: Hot water tank to compensate for fluctuations in demand
solar_thermal_water_treatment	Building energy efficiency: Additional solar thermal water treatment
swimming_pool_as_heat_storage_for_solar	Building energy efficiency: Indoor pool/swimming pool as heat storage for solar thermal system
power_plant_with_waste	Building energy efficiency: Combined heat and power plant with full utilization of waste heat
air_treatment_system_with_heat_recovery	Building energy efficiency: Air treatment system with heat recovery
air_treatment_system_with_compressor	Building energy efficiency: Air treatment with compressor systems
refrigeration_machines_as_a_heat_pump	Building energy efficiency: Refrigeration machine for simultaneous use as a heat pump through appropriate pipes
refrigeration_machine_with_ice_storage	Building energy efficiency: Refrigeration machine in combination with ice storage to compensate for fluctuations in demand
power/heat_coupling_system_with_heat_rec	Building energy efficiency: Power/heat coupling system with heat recovery and feeding of electrical energy into the network
energy_check_with_consultant	Energy check with a consultant has been carried out
energy_management_system_existent	Energy management system according to ISO 5001 (alternatively EMAS environmental management system) has been introduced
energy_representatitve_appointed	The energy representative is appointed in the hotel
timer/motion_detectors_in_outdoor_areas	Timers and/or motion detectors in outdoor areas (e.g. underground car park)
timer/motion_detectors_in_indoor_areas	Timers and/or motion detectors indoors (e.g. toilets/corridors)
80%_of_kitchen_appliances_cat_A_or_B_e	At least 80% of kitchen appliances have category A or B energy efficiency
use_of_reusable_towels_in_public_areas	Use of reusable cloth towel rolls in public areas
use_of_recycled_paper_in_public_toilets	Use of recycled paper for hand drying in public toilets/staff areas
information_to_raise_awareness_employees	Information to raise awareness among employees about energy efficiency (e.g. environmental tips in the workplace)
LED_in_whole_hotel:_30%_to_60%	LED in whole hotel: 30% to 60%
LED_in_whole_hotel:_60%_to_90%	LED in whole hotel: 60% to 90%
LED_in_whole_hotel:_>_90%	LED in hotel> 90%
water_consumption_tracked	Water consumption is being tracked
water_consumption_tracked_monthly	Water consumption is being tracked Monthly
water_consumption_tracked_yearly	Water consumption is being tracked Yearly
digital_monitoring_tool_for_water_consum	Additional: The hotel uses a digital monitoring tool for this
water_efficiency_use_of_flow_limiters	Water efficiency measures: Use of flow limiters/aerators
water_efficiency_taps	Water efficiency measures: Taps (mx1. 4 - 6 liters/min.)
water_efficiency_toilet_flush_	Water efficiency measures: Toilet flush (approx. 6.5 liters/per flush)
water_efficiency_showers	Water efficiency measures: Showers (ma1. 8 - 10 liters/min.)
water_efficiency_urinals	Water efficiency measures: Urinals (max. 2 liters/per flush)
water_efficiency_sensor_in_public_areas	Water efficiency measures: Use of fittings with sensor technology in public areas
water_toilet_flush_with_flush_stop	Water efficiency measures: Toilet flush with flush stop function/saving button
waiver_of_occupied_rooms_cleaning	Waiver of occupied rooms cleaning
central_descaling_system_is_available	Central descaling system is available
automated_irrigation_systems	Safe use of automated irrigation systems for green spaces without harming the population and the environment
rainwater_usage	Safe use of gray or rainwater without harming the population and the environment
waste_water_is_disposed_correctly	Waste water from hotel operations is disposed of in municipal or government approved treatment systems where available
use_cleaning_appliances_with_ecolabel	Use of environmentally friendly cleaning agents/chemicals (e.g. biodegradable agents with “EU Ecolabel” or “Blue Angel” certification)
information_for_guests_water_consumption	Information to raise awareness among guests about water conservation
information_for_employees_water_consum	Information to raise awareness among employees about water conservation (e.g. environmental tips in the workplace)
own_water_recycling_system	Own water recycling system available
own_biological_sewage_treatment_plant	own biological sewage treatment plant
waste_consumption_is_being_tracked	waste consumption is being tracked
waste_consumption_is_being_tracked_mont	waste consumption is being tracked monthly
waste_consumption_is_being_tracked_yearl	waste consumption is being tracked yearly
waste_separation_system_in_hotel_room	there is a waste separation system existint in the hotel room
waste_separation_system_in_public_areas	there is a waste separation system existint in public areas
waste_separation_system_in_personnel_are	there is a waste separation system existint in personnel areas (e.g. offices)
waste_separation_is_done_by_housekeeping	waste separation is done by housekeeping
laundry_in-house	the laundry is being washed In-house
laundry_outsourced_<10km	the laundry is outsourced with an external provider <10km to hotel site
laundry_outsourced_<20km	the laundry is outsourced with an external provider <20km to hotel site
laundry_outsourced_<30km	the laundry is outsourced with an external provider <30km to hotel site
laundry_sustainably_certified	the outsourced laundry provider is sustainably certified

Table 32: Binary/Dichotomous Variable Set
Source: Author’s own data

6.1.3. Data Cleaning

Data cleaning refers to detecting and repairing *dirty* data entries and is one of the perennial challenges in quantitative data analytics (Chu et al., 2016). For this research, a combination of quantitative and logical data cleaning was executed. These two techniques dominate data cleaning in quantitative research (Prokoshyna et al., 2015). Statistical outliers and extreme values were identified using box- and whisker plots and flagged as outliers using interquartile range and Median Absolute Deviation (MAD). Although both methods are standard, MAD is an alternative measure around the median that is less sensitive to extreme outliers and, therefore, increases accuracy (Leys et al., 2013).

The data cleaning process is outlined as follows: Not all hotels within the database have completed Step 2 (tool insertion) of the certification process. Therefore, a strict logical data cleaning was executed. When more than two consumption variables were missing[27] the hotel was excluded. The hotel was marked as irrelevant in the respective analysis section when only one consumption variable was missing. Additionally, in some instances, the reported annual consumption data did not align with a calendar year. Therefore, the yearly consumption data was assigned to the first month[28] of accounting. Likewise, occasionally submitted monthly data points were summarized to generate an annual figure. In addition, data was excluded when e.g., the heating is not separated from the rest of the building (being a multi-purpose asset) (2 data points) or hotels had significant renovation during the reporting year (2 data points). Furthermore, when oil or gas consumption liter was displayed, the numbers were recalculated in kWh.

Similar to the data cleaning process of the study of Becken and McLennan (2017), a thorough quantitative data cleaning was executed. Regarding the data cleaning process itself, the data was checked for errors and outliers, starting with total consumption and then moving to intensity metrics per room or per guest night basis. On the other hand, when data was inserted, but numbers were obviously distorted[29], the hotel was excluded. As a rule of thumb, consumption data were excluded when the data point was ten times higher than the average value. Erroneous data was amended or deleted, statistical outliers were rechecked for correct reporting. However, when analyzing the final box whisker graphs (see Figure 20 and Figure 21), there is an indication that some hotels consume up to five times more than the average hotel.

[27] Example: missing electricity AND water consumption figures of the respective hotel
[28] Example: when consumption data was submitted from March 2022 to February 2023, the data is allocated to reporting year 2022 (first month of accounting March 2022)
[29] Example: reported water consumption >10 times higher than in similar hotel category

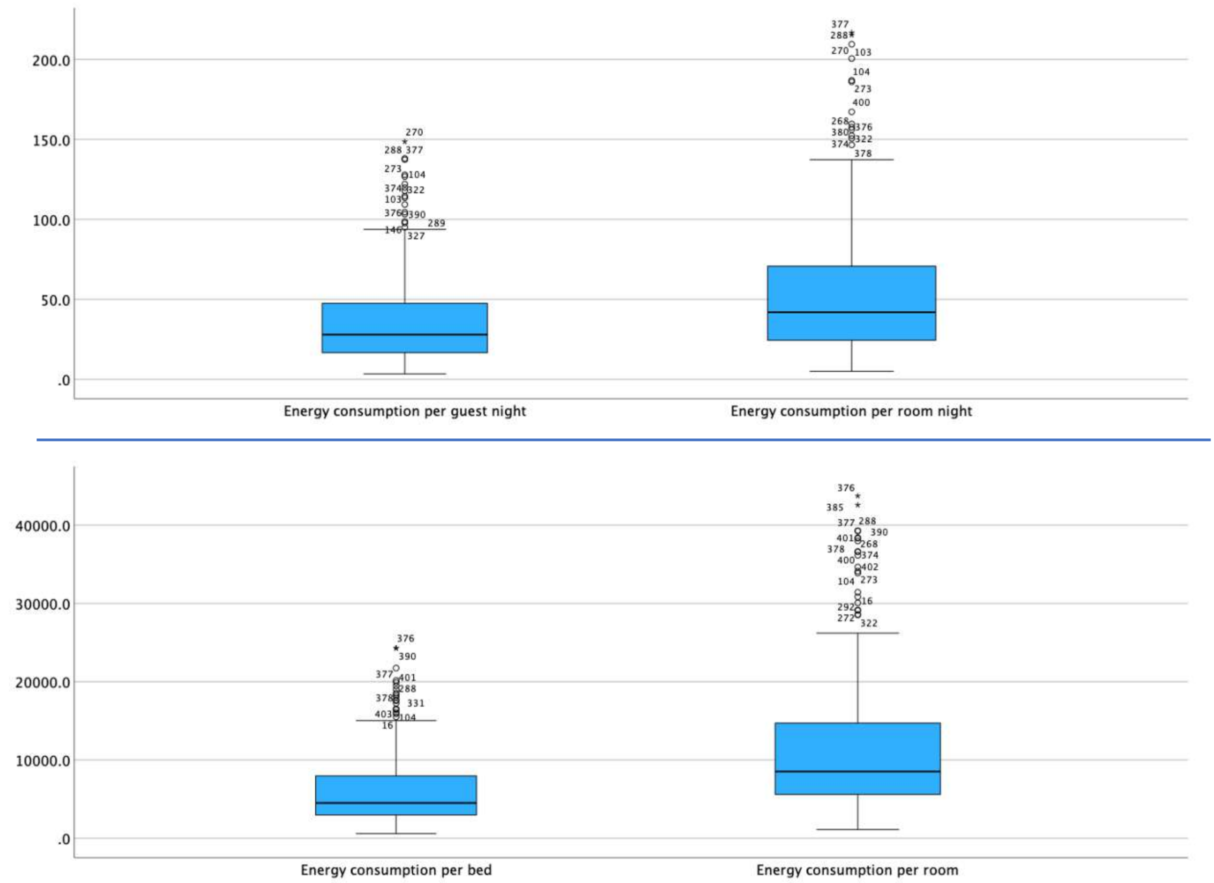

Figure 20: Box-Whisker Graphs for EUPGN and EUPOR in kWh
Source: Author's own data

The subsequent selected cases filter in SPSS used for the quantitative analysis consisted of the following equation:

Energy consumption analysis cases filter:

Select cases if condition is satisfied: electricity_per_rn < 200 & electricity_per_rn > 2 & ttl_electricity > 100 & energy_per_rn < 250 & ttl_heating > 1000 & ttl_guestnights < 600000 & energy_per_room < 45000 & energy_per_bed < 25000

Water consumption analysis cases filter:

Select cases if condition is satisfied: ttl_water_consumption > 100 & water_consumption_per_rn < 600 & water_consumption_per_rn > 80 & ttl_guestnights < 600000 & water_consumption_per_room < 180 & water_consumption_per_bed < 100

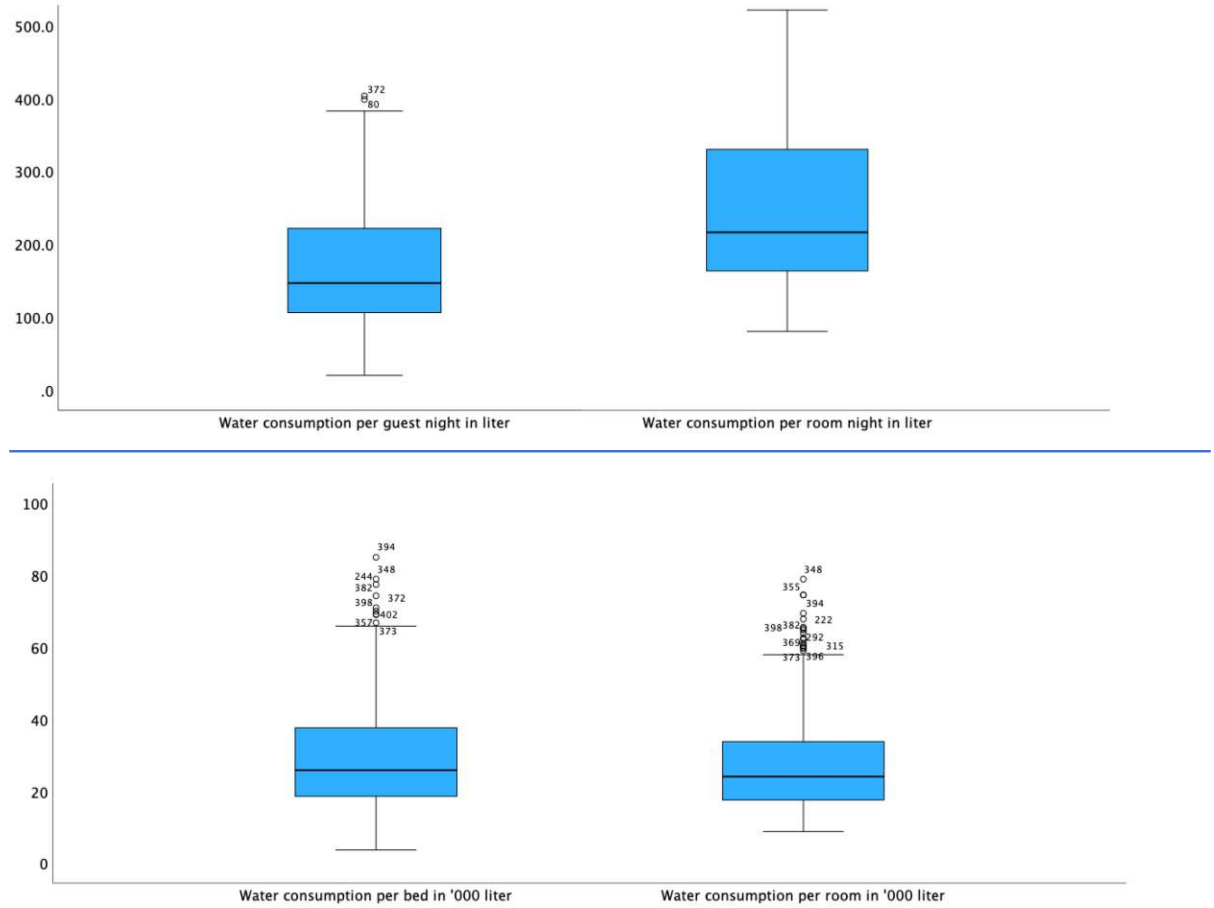

Figure 21: Box-Whisker Graphs for WUPGN and WUPOR, in thousand Liters
Source: Author's own data

Before data cleaning, the database consisted of 358 entries with hotel data. Erroneous data points were flagged and evaluated on an ongoing basis. During the screening process of the data set, the data of 57 hotel buildings did not fulfill the quality requirements (e.g., invalid or missing information in general, no data entries, abnormal consumption data, or ratios) and were subsequently removed for analysis. The detailed data-cleaning process is illustrated in Table 33. As all relevant data was checked line by line comparing absolute and relative figures, the data set is ultimately evaluated as robust. The comparatively large number of hotels with abnormal consumption figures may be due to the aforementioned difficulties and missing know-how in hotel staff executives to report consumption data figures. Therefore, intensive training in the data collection process is necessary to gain unified data (Warnken et al., 2004). The final data set comprises of 301 hotels for further analysis (distribution of the sample see Chapter 6.2.1.1).

Data cleaning Step	Data Points
Imported data set into SPSS	358
More than two consumption data points missing (e.g. electrizity and heating)	-4
Hotels with significant renovation in reporting year and therefore not reliable data	-2
Multi-purpose asset and e.g. heating is not separated from rest of the building	-2
Total resource consumption below 100	-18
Statistical outliers energy consumption ratios (consumption per rn 10x higher than average)	-13
Statistical outliers water consumption ratios (consumption per rn 10x higher than average)	-10
Adjustment according to boxplot analysis	-8
Total data for analysis	**301**

Table 33: Data Cleaning Process
Source: Author's own data

6.2. Results and Analysis

This section is dedicated to the analysis of the quantitative data set. Commencing with the description of the sample characteristics, descriptive and inferential statistics concerning energy, water, and waste consumption of the analyzed data set are displayed. Whereas the descriptive characteristics are shown together, inferential statistics are performed separately as not all hotels have provided data in each field. The results are then analyzed in relation to existing literature, with qualitative research findings integrated where applicable, to identify alignments, discrepancies, and contributions that enhance the overall understanding of the topic.

6.2.1. Descriptive Statistics

The sampled hotels possess a multitude of different variations and are deviating in their characteristics. To attain more insights into the heterogeneity of the data set, grouping in distinct hotel characteristics similar to other studies (Becken and McLennan, 2017; Huang et al., 2015; Yao et al., 2015) is performed in the upcoming section. The data includes general hotel characteristics such as age, room and bed number, occupancy rate, average rate as well as total energy and water figures and respective ratios per room and guest night. The clustering is analog to the qualitative research findings illustrated in Table 30. The following sections are structured as proposed within existing literature in operational factors (star-rating, location / operational concept, chain-affiliation, type of F&B board, existence of MICE and wellness area), physical factors (age, air-conditioning) and external factors (city / countryside, laundry outsourcing). Furthermore, hardware environmental retrofitting and operational environmental efforts are displayed and analyzed, clustered in star rating and location variables. The mean, median, standard deviation and variance are shown in detail.

6.2.1.1. Data Set Characteristics

The main description of the analyzed data set is displayed in Table 34. Totaling 38,610 rooms (72,556 beds) in 301 hotels, the smallest hotel consists of 15 rooms (30 beds) with one floor to the large-scale establishment with 1.052 rooms (2.500 beds), and the largest building consists of 20 floors. On average, hotels in the dataset comprise 128 rooms and 241 beds distributed across five floors. The mean occupancy rate is 60.6%, and the average daily rate amounts to 115.90 Euro (excluding VAT) resulting in a revenue per available room (REVPAR) of 66.4 Euro.

	Mean	Median	Standard Deviation	Variance
Building Year	1980	1996	59	3533
Number of floors	5	4	4	15
Number of restaurants	1	1	1	1
Number of rooms	128	112	76	5807
Number of beds	241	215	144	20668
Total guest nights	42443.2	37049.0	28416.6	807502522.6
Total room nights	28221.3	23652.0	18870.0	356075471.4
Av. room occupancy	60.6	64.2	13.7	188.4
Av. rate in Euro	115.9	96.2	65.6	4308.7
Av. REVPAR in Euro	66.4	52.6	52.1	2710.3
Total electrizity consumption in kWh	547840.5	357338.0	674028.9	4.5E+11
Electrizity consumption per guest night	12.9	9.5	11.7	137.9
Electrizity consumption per room night	19.2	13.8	17.1	292.3
Electrizity consumption per bed	2162.6	1637.9	1840.3	3386727.9
Electrizity consumption per room	4032.0	2981.5	3351.1	11229742.4
Total heating consumption in kWh	901915.6	601730.0	1013730.4	1.0E+12
Heating consumption per guest night	23.5	17.3	20.7	427.0
Heating consumption per room night	35.0	25.4	30.7	942.6
Heating consumption per bed	3935.4	3018.7	3392.3	11507972.1
Heating consumption per room	7347.0	5473.8	6342.7	40230042.5
Total energy consumption in kWh	1449756.1	1020856.3	1517428.8	2.3E+12
Energy consumption per guest night	36.4	27.9	27.8	773.7
Energy consumption per room night	54.2	41.9	41.0	1681.9
Energy consumption per bed	6083.8	4508.7	4529.5	20516415.7
Energy consumption per room	11384.5	8528.4	8535.3	72851691.8
Total water consumption in '000 liter	8289.6	5507.0	10234.2	104738218.4
Water consumption per guest night in liter	204.7	147.6	205.9	42384.8
Water consumption per room night in liter	306.2	217.9	314.3	98802.0
Water consumption per bed in '000 liter	35	25	36	1303
Water consumption per room in '000 liter	66.5	47.9	69.2	4789.6

Table 34: Descriptive Statistics Data Set Total

The oldest hotel in the dataset dates back to 1553, while the newest was built in 2022, resulting in a total age span of 469 years. This significant variation in building age is a defining characteristic of the hotel industry in Germany and Austria. On average, the hotels in the data set were built in 1980. However, it must be acknowledged that the sample hotels primarily report the year of initial construction, without accounting for ongoing maintenance or retrofitting measures. All hotels within the sample are open 365 days a year. Regarding resource consumption ratios, an EUPGN of 36.4 kWh and a WUPGN of 204.7 liters are found. The considerably high standard deviation, especially in total heating and energy consumption and respective ratios, indicates a significantly heterogeneous sample. Furthermore, the median tends to be lower than the mean values, indicating some hotels with significantly higher resource consumption than average. After detailed examination of these data points, this can be attributed to hotels with a high level of service, a large number of outlets, special uses, and large outdoor areas.

6.2.1.2. Data Set Characteristics Operational Factors

Quality Level Analysis

	Star Rating								
	Midscale (3 star)			Upscale (4 star)			Luxury (5 star)		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Building Year	1983	1994	54	1979	1997	64	1974	1998	50
Number of floors	5	4	2	5	4	5	4	4	2
Number of restaurants	1	1	1	1	1	1	2	2	1
Number of rooms	118	100	75	137	127	79	108	99	47
Number of beds	224	190	152	256	242	142	201	189	89
Total guest nights	39572.0	31839.2	29246.3	44451.0	40612.4	28717.9	40149.8	38220.5	18048.7
Total room nights	26109.6	20994.8	18014.9	29666.8	26334.8	19901.8	26838.4	24789.0	11624.6
Av. room occupancy	60.9	64.4	13.8	59.5	60.0	13.7	69.3	70.5	11.2
Av. rate in Euro	81.6	74.7	25.4	123.4	110.0	54.0	248.6	235.8	124.0
Av. REVPAR in Euro	46.5	48.1	23.8	67.7	61.8	44.6	173.6	165.5	96.0
Total electricity consumption in kWh	292541.8	213858.0	358692.6	663855.2	483553.0	760580.4	951712.7	671028.0	749167.9
Electricity consumption per guest night	7.8	5.9	6.7	14.9	11.3	12.0	23.8	20.0	18.6
Electricity consumption per room night	11.6	8.9	10.8	22.2	17.5	17.2	35.2	28.6	25.9
Electricity consumption per bed	1295.6	1034.8	924.0	2470.5	1993.5	1912.8	4371.0	4639.3	2455.0
Electricity consumption per room	2407.5	1892.1	1777.8	4607.6	3978.3	3397.2	8183.2	8231.5	4662.1
Total heating consumption in kWh	654393.0	538014.0	615229.4	1008023.6	680309.0	1147170.2	1355445.6	1095622.5	1249022.8
Heating consumption per guest night	20.8	16.0	18.5	24.4	18.7	21.5	31.7	28.5	23.3
Heating consumption per room night	30.5	22.5	27.4	36.6	28.1	32.0	47.0	44.6	33.8
Heating consumption per bed	3303.3	2758.5	2532.1	4071.8	3327.9	3506.7	6402.3	4807.2	5262.4
Heating consumption per room	6066.6	5068.8	4664.1	7669.4	5902.4	6633.9	11896.1	9036.4	9443.2
Total energy consumption in kWh	946934.8	763700.5	856773.2	1671878.8	1121895.0	1702568.6	2307158.3	1998974.0	1857885.6
Energy consumption per guest night	28.6	22.6	22.3	39.3	31.1	28.7	55.4	50.8	35.2
Energy consumption per room night	42.1	32.1	34.0	58.8	47.5	41.7	82.2	81.9	51.1
Energy consumption per bed	4608.7	3849.7	3057.8	6529.5	5342.7	4612.9	10600.0	9480.4	6923.9
Energy consumption per room	8495.6	6727.2	5838.7	12237.3	10399.4	8495.1	20427.4	18658.2	13612.6
Total water consumption in '000 liter	5617.7	3951.0	5596.5	9489.7	6065.0	11886.3	11539.4	11583.0	10454.5
Water consumption per guest night in liter	160.2	121.6	161.8	221.6	160.2	220.8	287.6	281.7	234.9
Water consumption per room night in liter	234.6	178.7	243.9	333.6	235.3	337.2	437.9	432.2	362.7
Water consumption per bed in '000 liter	27	22	24	38	27	39	59	56	50
Water consumption per room in '000 liter	49.9	42.5	44.0	71.1	52.9	75.1	112.1	108.4	95.5

Table 35: Descriptive Statistics Star Rating
Source: Author's own data

Analysis of Table 35 reveals that the majority of the sample comprises 3-star (midscale, 108 hotels) and 4-star (upscale, 175 hotels) segments, representing the dominant categories in the dataset. 18 hotels offer luxury services and are categorized as 5-star properties. Hotels in low categories (1- and 2-star) are not evident in the data sample. The building age of the properties is similar between the categories. As postulated by previous research, an increase in quality level is accompanied by a rise in the average rate (3-star 81.6 Euro, 4-star 123.4 Euro, 5-star 248.6 Euro). The average occupancy rate is in 5-star properties (69.3%), slightly higher than in 4-star (60.0%) and 3-star (60.9%).

Furthermore, 5-star properties have two restaurants on average, while lower categories generally have one. With regard to resource consumption, a pattern is evident when the star rating and associated service level rise; consumption figures excel as well. For example, an occupied room in a luxury property consumes almost double the amount of water (437.9 liters vs. 234.6 liters, +86%) and the amount of energy (42.1 kWh vs. 81.9 kWh, +94,5%). This effect is also evident when analyzing the trend lines in Figure 22. This result is similar to other studies claiming that resource consumption increases with star rating/service level (Oluseyi et al., 2016; Priyadarsini et al., 2009; Santiago, 2021; Tang et al., 2016; Xuchao et al., 2010).

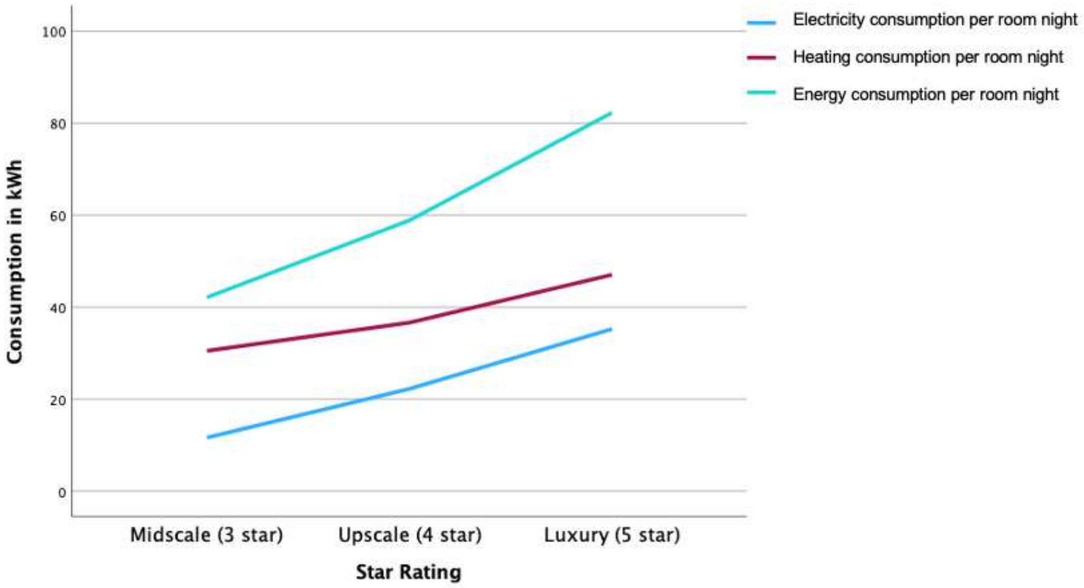

Figure 22: Quality Level Comparison Electricity, Heating, Energy Consumption
Source: Author's own data
Please note: The graph represents an extrapolation derived from observed data patterns

F&B Outlets Analysis

When analyzing the type of board, i.e., whether the hotel only offers breakfast service (239 hotels) or possesses a full restaurant (60 hotels), the majority of general characteristics are similar (see Table 36). Hotels with no F&B outlet were excluded from the analysis due to a limited number of hotels (1 hotel). As a result of the increased service product and quality level, when having a full-service hotel, the average rate increases significantly (Breakfast only 110.6 Euro, Full Restaurant 137.7 Euro). When looking at resource consumption, the higher the level of the F&B board, an increase in energy consumption ratios is observed (e.g., EUPRN 48.4 kWh breakfast only compared to 78.2 kWh full restaurant). Furthermore, water resource figures increase significantly when full-board is offered (e.g., water consumption per room night 277 liters breakfast only, 435.7 liters with full restaurant).

	Type of F&B board					
	Breakfast only			Restaurant		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Building Year	1978	1996	64	1985	1997	37
Number of floors	5	4	4	4	4	2
Number of restaurants	1	1	1	1	1	1
Number of rooms	130	111	80	119	118	58
Number of beds	246	210	151	222	220	109
Total guest nights	44272.9	37230.0	30357.9	35368.3	36017.9	17824.9
Total room nights	29401.3	23849.1	20188.9	23603.1	23181.8	11758.3
Av. room occupancy	61.9	64.4	13.6	55.7	56.8	13.3
Av. rate in Euro	110.6	90.0	64.4	137.7	114.1	67.4
Av. REVPAR in Euro	64.0	51.4	50.7	76.9	56.6	57.2
Total electricity consumption in kWh	503912.3	331023.0	645530.0	725362.0	524394.5	764575.8
Electricity consumption per guest night	11.2	8.0	10.4	19.7	15.6	14.2
Electricity consumption per room night	16.8	11.9	15.3	29.0	25.2	20.4
Electricity consumption per bed	1925.2	1402.5	1625.6	3133.0	2190.5	2311.7
Electricity consumption per room	3594.6	2632.4	2938.5	5823.1	4260.7	4253.5
Total heating consumption in kWh	853889.8	557614.0	1043470.0	1109929.9	878229.5	877752.1
Heating consumption per guest night	21.2	15.6	20.2	33.3	27.3	20.0
Heating consumption per room night	31.6	23.2	30.5	49.2	44.7	28.0
Heating consumption per bed	3609.4	2754.7	3343.6	5311.4	4486.3	3298.0
Heating consumption per room	6741.9	4925.0	6259.4	9913.4	8526.8	6130.9
Total energy consumption in kWh	1357802.1	897566.0	1506121.2	1835291.8	1331613.5	1533569.6
Energy consumption per guest night	32.4	24.6	25.6	53.0	44.4	30.4
Energy consumption per room night	48.4	35.5	38.6	78.2	69.4	42.4
Energy consumption per bed	5516.7	4222.3	4230.5	8444.4	7272.0	4983.9
Energy consumption per room	10353.5	7464.3	8063.3	15696.5	13930.8	9143.4
Total water consumption in '000 liter	7743.8	5166.0	9580.3	10713.3	6259.0	12591.9
Water consumption per guest night in liter	185.7	141.7	198.3	289.4	245.5	220.1
Water consumption per room night in liter	277.0	201.5	302.3	435.7	354.0	338.0
Water consumption per bed in '000 liter	33	25	35	48	32	40
Water consumption per room in '000 liter	60.9	46.8	65.9	91.5	59.3	78.4

Table 36: Descriptive Statistics F&B Service Type
Source: Author's own data

Therefore, a strong effect of the type of board on resource consumption can be postulated. This result is similar to the qualitative research conducted and claimed in other study results (Bohdanowicz and Martinac, 2007; Deng and Burnett, 2002; Deyà Tortella and Tirado, 2011).

Wellness Outlet Analysis

Scholars found that hotels with wellness areas have excessive water consumption (Bohdanowicz and Martinac, 2007; Deyà Tortella and Tirado, 2011; Warnken et al., 2005). In the respective sample, 114 hotels possess a wellness area. The analysis of the descriptive statistics (Table 37) illustrate that while the hotel size, age and occupancy level are similar, hotels with wellness areas can generate almost double the rate (92.5 Euro non-wellness, 154.3 Euro wellness), indicating a difference in quality and service level of a wellness hotel. Furthermore, the higher number of restaurants in wellness hotels indicates a greater availability of F&B outlets, reflecting a broader range of services and amenities offered in comparison to non-wellness hotels. Resource consumption figures vary as well considerably.

	Wellness					
	non-existent			existent		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Building Year	1979	1996	68	1982	1996	42
Number of floors	5	4	4	4	4	3
Number of restaurants	1	1	1	2	1	1
Number of rooms	126	108	77	132	120	75
Number of beds	239	204	153	244	227	128
Total guest nights	43083.5	35040.0	31665.1	41392.9	37879.1	22171.8
Total room nights	28391.2	23498.7	20093.7	27942.7	24065.9	16751.6
Av. room occupancy	61.5	64.4	13.7	59.2	60.0	13.7
Av. rate in Euro	92.5	79.5	36.3	154.3	134.3	83.0
Av. REVPAR in Euro	55.3	48.1	32.6	84.7	72.9	70.0
Total electricity consumption in kWh	396415.0	236994.0	480293.1	796231.4	567240.0	852203.3
Electricity consumption per guest night	9.2	6.6	7.7	18.9	16.1	14.5
Electricity consumption per room night	13.8	9.9	11.6	28.1	24.3	20.7
Electricity consumption per bed	1576.8	1150.5	1249.6	3123.4	2547.3	2218.5
Electricity consumption per room	2946.1	2203.4	2343.9	5813.3	4765.7	3952.0
Total heating consumption in kWh	619481.0	473057.0	569667.5	1365207.5	1063195.5	1358513.3
Heating consumption per guest night	16.7	15.0	12.3	34.6	27.5	26.1
Heating consumption per room night	24.7	21.1	17.5	52.1	43.5	39.1
Heating consumption per bed	2820.6	2462.2	1911.9	5764.0	4612.4	4371.0
Heating consumption per room	5216.6	4740.0	3447.8	10841.7	8792.1	8210.1
Total energy consumption in kWh	1015896.0	767460.0	960534.8	2161438.9	1518313.5	1942146.5
Energy consumption per guest night	26.0	22.2	16.8	53.5	45.9	33.3
Energy consumption per room night	38.4	31.6	24.1	80.1	72.6	49.2
Energy consumption per bed	4352.6	3662.4	2617.1	8923.5	7737.5	5486.3
Energy consumption per room	8051.0	6630.7	4697.5	16852.7	14833.3	10418.1
Total water consumption in '000 liter	6296.2	4385.5	7166.5	11494.0	8084.0	13229.7
Water consumption per guest night in liter	153.7	129.3	140.8	286.8	228.7	261.1
Water consumption per room night in liter	225.0	191.0	189.9	436.8	322.6	416.0
Water consumption per bed in '000 liter	27	23	25	49	36	46
Water consumption per room in '000 liter	49.9	43.6	43.0	93.2	67.4	91.7

Table 37: Descriptive Statistics Wellness
Source: Author's own data

On average, the WUPGN in wellness hotels is nearly twice as high as in hotels without a wellness area, amounting to 286.8 liters compared to 153.7 liters. A similar pattern is observed across other resource consumption variables, including electricity and heating, as well as overall energy use per guest night (EUPGN), which increases from 26 kWh in hotels without a wellness area to 53.5 kWh in those with one. These findings suggest that the presence of a wellness area has a substantial impact on overall resource consumption.

MICE Outlet Analysis

Similar to wellness facilities, hotels with extensive MICE (Meetings, Incentives, Conferences, and Exhibitions) areas may exhibit higher environmental resource consumption. Within the dataset, 225 hotels feature designated MICE areas, while 76 hotels do not. Due to the fact that MICE hotels often possess higher quality levels and numerous other outlets, the average rate is slightly higher (123.8 Euro) than hotels without this outlet (92.7 Euro). While analyzing the key resource variables illustrated in Table 38, no significant differences in water consumption per room night are observed (WUPRN 284.6 liters no MICE area, 313.4 liters MICE area existent). However, EUPRN is hugely affected (38 kWh no MICE area, 59.7 kWh MICE area existent), finding that the extensive meeting areas need heating, air-conditioning, and lightning, but no additional water resources.

	MICE					
	no MICE area			MICE area existent		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Building Year	1987	2002	60	1978	1995	59
Number of floors	5	5	2	5	4	4
Number of restaurants	1	1	0	1	1	1
Number of rooms	119	98	79	131	120	75
Number of beds	230	189	161	245	221	138
Total guest nights	43436.6	32806.2	31621.9	42107.6	37230.0	27317.1
Total room nights	28301.6	23327.2	19591.2	28194.2	24282.7	18664.8
Av. room occupancy	64.6	64.4	11.5	59.3	60.3	14.2
Av. rate in Euro	92.7	74.7	36.1	123.8	105.2	71.3
Av. REVPAR in Euro	58.5	48.1	25.8	69.1	56.0	58.1
Total electricity consumption in kWh	316329.1	208678.5	352072.8	626039.9	416374.0	736632.4
Electricity consumption per guest night	8.0	4.9	8.3	14.6	11.1	12.3
Electricity consumption per room night	12.2	7.6	13.6	21.6	16.8	17.5
Electricity consumption per bed	1382.7	900.2	1190.5	2426.0	1887.8	1945.6
Electricity consumption per room	2622.0	1785.6	2341.1	4508.3	3732.6	3507.5
Total heating consumption in kWh	676807.7	387011.0	1037969.7	977952.1	680309.0	996285.9
Heating consumption per guest night	17.3	11.2	17.5	25.6	20.2	21.2
Heating consumption per room night	25.8	17.0	26.8	38.2	30.6	31.3
Heating consumption per bed	3057.1	2040.5	3087.4	4232.1	3466.1	3445.4
Heating consumption per room	5698.3	4017.4	5756.9	7904.0	6446.8	6445.9
Total energy consumption in kWh	993136.8	662579.5	1340109.2	1603992.0	1094000.0	1545278.7
Energy consumption per guest night	25.2	16.1	24.3	40.2	32.8	28.0
Energy consumption per room night	38.0	24.0	38.2	59.7	50.0	40.5
Energy consumption per bed	4422.5	3011.4	3988.5	6644.9	5384.1	4571.5
Energy consumption per room	8291.9	5880.8	7531.7	12429.1	10385.2	8616.0
Total water consumption in '000 liter	6779.7	4735.0	5847.3	8785.7	5696.0	11278.0
Water consumption per guest night in liter	190.9	137.1	182.3	209.3	147.8	213.3
Water consumption per room night in liter	284.6	198.0	277.9	313.4	221.6	325.7
Water consumption per bed in '000 liter	33	28	27	36	25	39
Water consumption per room in '000 liter	61.7	47.5	49.4	68.0	48.0	74.6

Table 38: Descriptive Statistics MICE
Source: Author's own data

Chain Affiliation Analysis

Another differentiation of the sample hotels is whether they belong and are managed by an international chain (chain affiliated, 191 hotels) or independently owned and operated (not chain affiliated, 110 hotels). Interestingly, the average chain-affiliated hotel in the sample has more rooms (144 rooms compared to 101 rooms) and is younger in building age (1998 compared to 1963) than independently owned properties. This complements the fact that international hotel chains generally have larger properties to gain economies of scale (Ribaudo et al., 2020). Furthermore, a strong focus of chain-affiliated hotels is within city locations (80.4% of all chain-affiliated hotels). Unlike other studies, chain-affiliated does not generate a price premium (av. rate 134.4 Euro unaffiliated hotels, av. rate 105.3 Euro affiliated hotels). Therefore, the findings support Carvell et al. (2016) in concluding that affiliation offers no significant economic advantages.

	Chain Affiliation					
	Not chain affiliated			Chain affiliated		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Building Year	1963	1991	75	1990	1998	45
Number of floors	4	3	2	6	5	4
Number of restaurants	1	1	1	1	1	1
Number of rooms	101	85	76	144	129	72
Number of beds	183	160	129	274	246	142
Total guest nights	33482.1	27156.8	25360.4	47604.0	40612.4	28857.9
Total room nights	22908.4	18450.8	19029.0	31281.1	27166.4	18131.1
Av. room occupancy	62.0	62.7	14.1	59.8	64.4	13.5
Av. rate in Euro	134.4	109.4	83.7	105.3	85.0	49.7
Av. REVPAR in Euro	77.3	64.3	69.4	60.2	48.1	37.5
Total electricity consumption in kWh	516010.6	272004.0	731750.0	566171.9	380155.0	639711.8
Electricity consumption per guest night	14.3	10.5	11.7	12.1	8.2	11.7
Electricity consumption per room night	20.6	16.2	15.7	18.4	12.0	17.8
Electricity consumption per bed	2478.5	1939.1	1926.3	1980.6	1402.5	1768.6
Electricity consumption per room	4521.0	3897.8	3318.7	3750.4	2551.8	3345.9
Total heating consumption in kWh	857437.6	485981.0	947247.4	927531.2	637706.0	1051686.8
Heating consumption per guest night	27.3	23.3	23.4	21.4	15.9	18.6
Heating consumption per room night	39.8	35.2	33.4	32.3	23.7	28.8
Heating consumption per bed	4773.3	4127.4	3977.2	3452.9	2736.0	2907.8
Heating consumption per room	8833.1	7655.2	7342.0	6491.2	4923.7	5530.1
Total energy consumption in kWh	1373448.2	868252.5	1535142.4	1493703.1	1036998.0	1509429.1
Energy consumption per guest night	41.5	33.2	30.1	33.5	25.8	26.0
Energy consumption per room night	60.5	53.0	41.8	50.7	37.0	40.2
Energy consumption per bed	7251.7	6439.5	5021.4	5411.1	4077.5	4084.7
Energy consumption per room	13433.0	12023.3	9346.0	10204.8	7342.2	7816.1
Total water consumption in '000 liter	7940.0	4639.0	11319.8	8497.4	5697.0	9558.9
Water consumption per guest night in liter	238.8	181.7	244.2	184.5	133.6	177.0
Water consumption per room night in liter	352.7	252.7	371.7	278.6	197.7	272.0
Water consumption per bed in '000 liter	42	32	44	32	24	30
Water consumption per room in '000 liter	78.1	57.2	86.7	59.5	45.1	55.4

Table 39: Descriptive Statistics Chain Affiliation
Source: Author's own data

Regarding resource consumption figures, a slight difference is revealed in energy (EUPGN 41.5 kWh unaffiliated vs. 33.5 kWh affiliated) as well as water consumption (WUPGN 238.8 liters unaffiliated vs. 184.5 liters affiliated). Therefore, it can be concluded that chain-affiliated hotels exhibit slightly higher resource efficiency. However, it must be acknowledged that this outcome may be influenced by confounding factors such as star rating, type of board, and location. Nonetheless, the finding aligns with insights from the qualitative analysis, which suggest a modest relationship between resource consumption and chain affiliation.

6.2.1.3. Operational Environmental Efforts

The analysis of dataset characteristics indicates that quality level and location significantly influence resource consumption in the hotel industry. Accordingly, the following descriptive analysis of retrofitting and operational environmental efforts accounts for these factors. While hardware retrofitting enhances energy efficiency, efficient operational practices remain essential for further reductions in resource use. As summarized in Table 40, this section focuses on operational environmental initiatives.

Interestingly, 59% of the sample hotels have conducted an energy check with an external consultant. However, an energy management dashboard / system does not exist throughout the data set. Approximately one-third of the hotels in the sample employ a digital monitoring tool to track water consumption. Among those, 29% of hotels constructed before 2018 have implemented such digitalized tools, whereas nearly 50% of hotels built after 2018 have adopted this technology. While being highlighted by different scholars (Beccali et al., 2009; Hu et al., 2015) as well as the findings of the qualitative interview process, creating environmental awareness among guests and employees is perceived as crucial. This is done via a booklet about energy efficiency (83% of the total sample) or for employees (94% of the sample). Furthermore, 83% of the sampled hotels issue an official document related to CSR/ESG policies. However, it has to be acknowledged that what this report needs to consist of is not further defined.

		Location											
		City				Countryside				Total			
		Star Rating				Star Rating				Star Rating			
		Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total
CSR/ESG official document	existent	83.3%	94.6%	40.0%	87.8%	70.8%	83.2%	76.9%	79.0%	77.8%	88.0%	66.7%	83.1%
CSR/ESG representative appointed	existent	38.3%	97.3%	100.0%	71.9%	75.0%	96.0%	100.0%	90.1%	54.6%	96.6%	100.0%	81.7%
Energy check with consultant	existent	36.7%	70.3%	60.0%	55.4%	50.0%	61.4%	92.3%	60.5%	42.6%	65.1%	83.3%	58.1%
Energy management system	existent	0.0%	1.4%	0.0%	0.7%	0.0%	7.9%	0.0%	4.9%	0.0%	5.1%	0.0%	3.0%
Digital monitoring tool for water consumption	existent	38.3%	43.2%	20.0%	40.3%	25.0%	22.8%	23.1%	23.5%	32.4%	31.4%	22.2%	31.2%
Information to raise environmental awareness for employees	existent	88.3%	95.9%	100.0%	92.8%	87.5%	98.0%	100.0%	95.1%	88.0%	97.1%	100.0%	94.0%
Information for guests on water efficiency measures	existent	81.7%	90.5%	60.0%	85.6%	79.2%	94.1%	84.6%	88.9%	80.6%	92.6%	77.8%	87.4%
Information for employees on water efficiency measures	existent	85.0%	93.2%	100.0%	89.9%	85.4%	97.0%	100.0%	93.8%	85.2%	95.4%	100.0%	92.0%
Use of reusable towels in public areas	existent	10.0%	18.9%	20.0%	15.1%	10.4%	18.8%	15.4%	16.0%	10.2%	18.9%	16.7%	15.6%
Use of recycled paper in public toilets	existent	55.0%	81.1%	60.0%	69.1%	66.7%	77.2%	100.0%	75.9%	60.2%	78.9%	88.9%	72.8%
Cleaning appliances with ecolabel	existent	25.0%	77.0%	100.0%	55.4%	43.8%	89.1%	92.3%	75.9%	33.3%	84.0%	94.4%	66.4%
Waiver of occupied rooms cleaning	existent	96.7%	89.2%	60.0%	91.4%	85.4%	85.1%	69.2%	84.0%	91.7%	86.9%	66.7%	87.4%
Water efficient cleaning with flushing 1-3 times	existent	91.7%	97.3%	80.0%	94.2%	91.7%	96.0%	100.0%	95.1%	91.7%	96.6%	94.4%	94.7%

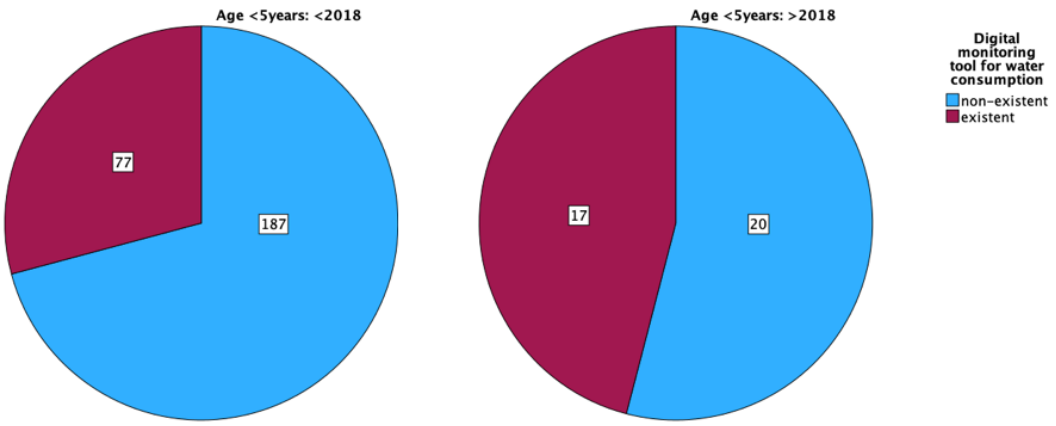

Table 40: Operational Environmental Efforts Comparison
Source: Author's own data

Regarding the cleaning routine of hotel rooms, especially higher-class hotels agree on water-efficient cleaning and using cleaning appliances with ecolabel certification. Most hotels offer not to clean the hotel room during the guest stay to save environmental resources (88% of hotels). While the majority of hotels use recycled paper towels in public areas (73% of hotels in total), the use of reusable towels in public toilets is limited (16% of hotels in total). As a result, it can be concluded that higher hotel quality is associated with greater implementation of operational environmental measures.

6.2.1.4. Data Set Characteristics Physical Factors

Hotel Size Analysis

	Rooms Clustering											
	<50 Rooms			50-100 Rooms			100-200 Rooms			>200 Rooms		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Building Year	1918	1978	125	1971	1990	49	1997	2000	25	1998	2006	27
Number of floors	3.2	3.0	1.5	4.1	4.0	1.5	5.4	4.0	5.0	6.7	6.0	3.8
Number of restaurants	1.1	1.0	.5	1.3	1.0	.8	1.5	1.0	.8	1.5	1.0	.9
Number of rooms	35	36	10	77	78	13	141	142	28	266	235	71
Number of beds	64	68	19	144	142	32	269	260	59	496	452	130
Total guest nights	11726.0	11534.0	4749.8	26475.4	25696.0	7888.3	46393.8	46282.0	14240.3	87867.4	79927.7	37217.5
Total room nights	7845.8	7555.5	3139.6	17579.3	16919.1	4517.1	30473.9	30178.2	8806.4	59141.4	53852.8	25021.9
Av. room occupancy	61.5	63.4	14.7	63.3	64.4	13.0	59.2	61.4	13.0	59.9	61.0	16.0
Av. rate in Euro	117.2	102.5	51.8	120.4	91.3	86.0	117.2	97.8	60.7	108.5	102.2	49.8
Av. REVPAR in Euro	59.4	55.0	48.3	76.5	51.5	67.1	65.8	55.4	46.5	59.3	48.1	40.1
Total electricity consumption in kWh	136178.7	82213.5	131722.4	284552	187869.0	278884.6	613458.8	503362.0	480564.2	1238533.7	860054.0	1223923.7
Electricity consumption per guest night	11.5	8.0	10.5	11.5	6.4	11.8	13.9	10.7	11.9	14.6	11.9	12.7
Electricity consumption per room night	17.3	12.8	15.6	17.0	10.2	17.2	21.0	15.9	17.5	21.4	17.7	17.4
Electricity consumption per bed	1952.9	1623.6	1536.8	1999.3	1222.4	1925.8	2296.3	1863.3	1749.2	2443.3	1979.6	2206.2
Electricity consumption per room	3716.3	3109.6	3012.7	3686.8	2225.4	3456.6	4338.7	3595.9	3302.6	4439.3	3854.4	3629.9
Total heating consumption in kWh	316446.6	210206.0	314414.6	617482	456670.0	475336.2	964767.6	687066.0	935579.6	1788410.3	1286101.0	1633676.7
Heating consumption per guest night	28.4	25.2	26.1	24.2	20.0	17.1	22.3	16.1	21.2	22.0	17.3	17.8
Heating consumption per room night	42.4	38.9	38.9	36.1	28.1	26.1	33.5	24.0	31.3	32.5	26.5	26.5
Heating consumption per bed	4698.0	4509.3	3870.0	4271.5	3569.7	3032.0	3613.5	2736.0	3341.1	3703.9	2683.8	3526.1
Heating consumption per room	8877.9	8359.2	7519.9	7980.0	6358.3	5778.5	6798.8	5127.4	6168.4	6778.6	5030.1	6458.5
Total energy consumption in kWh	452625.3	344523.5	372779.4	902034	653766.8	682264.0	1578226.4	1104656.0	1232524.3	3026944.0	2135156.5	2506202.4
Energy consumption per guest night	39.9	34.5	32.1	35.8	26.9	25.8	36.2	26.3	28.3	36.6	29.0	26.5
Energy consumption per room night	59.7	56.7	47.3	53.1	38.7	39.0	54.4	41.9	41.5	53.9	41.7	38.0
Energy consumption per bed	6650.9	6186.8	4448.0	6232.4	4464.3	4428.6	5923.9	4413.8	4474.6	6078.2	4217.2	5034.8
Energy consumption per room	12594.2	12285.7	8775.2	11744.1	8725.7	8704.6	11171.6	8460.3	8330.3	11010.2	6834.2	8845.3
Total water consumption in '000 liter	2839.5	1617.0	3791.1	5644.3	3916.0	5408.5	9383.5	6039.0	11299.5	14639.0	11038.0	13278.7
Water consumption per guest night in liter	247.5	160.2	250.9	214.7	155.7	187.0	205.6	143.1	227.6	164.7	138.4	135.1
Water consumption per room night in liter	363.0	234.8	355.1	318.6	230.5	288.7	312.5	219.0	353.1	246.9	198.8	211.0
Water consumption per bed in '000 liter	41.1	27.7	41.6	38.9	29.5	33.7	34.9	23.8	40.3	29.1	23.5	23.1
Water consumption per room in '000 liter	76.8	49.4	78.1	72.0	54.9	63.1	66.4	47.0	78.4	54.4	44.6	44.8

Table 41: Descriptive Statistics Room Cluster
Source: Author's own data

To validate the findings of the qualitative research phase, four clusters are built to analyze resource consumption patterns to a hotel's size (see Table 41). Interestingly, there is a trend that larger hotels tend to be younger in age than smaller hotels (building year: <50 rooms 1918, >200 rooms 1998). Furthermore, the number of floors (<50 rooms 3.2, >200 rooms 6.7) and restaurants (<50 rooms 1.1, >200 rooms 1.5) increases with number of rooms. The financial performance KPIs, including average rate and occupancy, are nearly identical across the four clusters, simplifying the analysis of resource consumption. The resource consumption results reveal a contradictory pattern. Interestingly, while electricity consumption per room night increases with hotel size, the heating consumption decreases. The resulting energy consumption per room night indicates a small decrease when the property gets larger (EUPRN <50 rooms 59.7 kWh, >200 rooms 53.9 kWh). This finding is confirmed when analyzing the trend line displayed in Figure 23. This suggests that larger hotel or accommodation facilities may benefit from improved energy efficiency in heating, while electricity use per room night does not significantly vary with hotel size. To the author's knowledge, no similar pattern is found in previous academic studies. Further investigations are necessary to explain this effect.

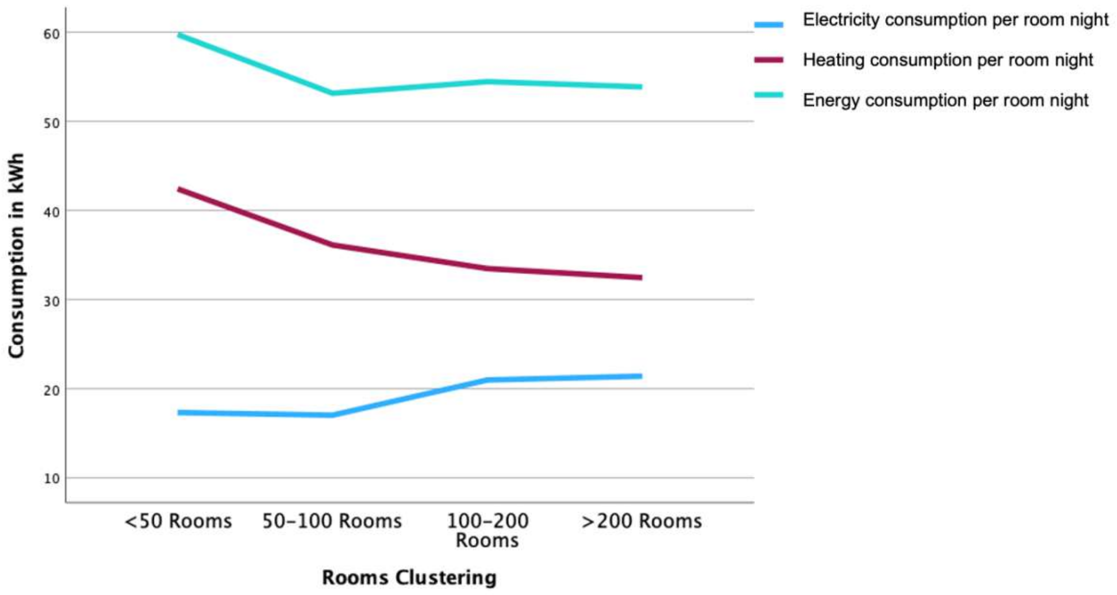

Figure 23: Room Cluster Comparison Electricity, Heating, Energy Consumption
Source: Author's own data
Please note: The graph represents an extrapolation derived from observed data patterns

Nevertheless, water consumption figures decrease substantially when the property gets larger in size (WUPRN <50 rooms 363 liters, >200 rooms 246.9 liters). The reasoning for this finding might be that large-scale properties are generally in the 3- and 4-star segment, while smaller properties are generally more luxurious and thus consume more water. However, this result would refute the theory that water consumption heavily depends on the user (Deyà Tortella and Tirado, 2011). Similar to the energy consumption pattern, this result can only be partly explained. Therefore, it can be concluded that larger hotels are generally not more resource-efficient in intensity values, as postulated by the experts in the qualitative research phase.

Building Age Analysis

When considering building age, the differentiation target was to construct three groups of comparative size (Table 42). Therefore, clustering occurs with hotels built before 1950 (39 hotels), between 1950 and 2000 (137 hotels), and after 2000 (125 hotels) (see Figure 24). Interestingly, the number of rooms is strongly increasing the younger a hotel is (75 rooms in hotels built before 1950, 151 rooms in hotels built after 2000). On the other side, performance metrics (occupancy level and average rate) are similar across all three groups, indicating an evenly spread sample across the quality level spectrum. With regard to resource consumption, the effect of heating and total energy consumption is evident. Although electricity consumption is not affected by building age, heating consumption is strongly decreasing the newer a hotel is (heating per guest night 32.3 kWh before 1950, 20.4 kWh after 2000). As a result, EUPGN is slightly lower in newer hotels than in older ones (46.2 kWh before 1950, 35 kWh after 2000). Regarding water consumption, hotels built before 1950 used somewhat more water per guest night (360 liters) than the other two groups (>2000 316 liters, 1950-2000 281 liters).

	Building Age Cluster								
	built > 2000			built between 1950 - 2000			built < 1950		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Number of floors	6	5	5	4	4	2	4	4	2
Number of restaurants	1	1	1	1	1	1	2	1	1
Number of rooms	151	146	79	123	105	67	75	58	69
Number of beds	290	274	147	225	201	127	142	114	127
Total guest nights	51773.6	47677.8	30216.9	38183.3	34164.0	21498.8	27502.2	18125.3	34065.7
Total room nights	33704.3	30404.5	20050.6	26092.1	23230.0	14567.7	18127.2	12335.3	22801.8
Av. room occupancy	61.5	64.4	12.8	59.5	63.0	13.9	61.7	60.4	16.0
Av. rate in Euro	125.0	105.2	72.9	103.9	85.0	55.2	129.1	107.8	69.1
Av. REVPAR in Euro	76.1	60.8	55.8	56.0	48.1	45.4	72.2	63.0	56.1
Total electricity consumption in kWh	735553.1	483122.0	833910.8	431795.0	281332.0	485345.2	353844.8	154903.0	520896.7
Electricity consumption per guest night	14.6	10.1	12.6	11.1	9.0	8.7	13.8	9.3	16.6
Electricity consumption per room night	22.3	16.1	19.0	16.2	12.4	12.9	20.0	13.7	21.7
Electricity consumption per bed	2488.3	1956.1	2020.2	1830.9	1425.6	1412.2	2283.7	1625.1	2349.7
Electricity consumption per room	4730.3	3750.0	3699.3	3355.7	2512.8	2669.8	4169.8	3442.4	3900.9
Total heating consumption in kWh	1007213.9	601730.0	1227531.5	871124.5	615562.0	884342.1	672585.0	540591.0	550601.5
Heating consumption per guest night	20.4	15.0	18.5	23.9	18.7	20.2	32.3	25.3	26.2
Heating consumption per room night	31.4	21.2	28.3	34.6	26.1	29.4	48.4	42.9	38.7
Heating consumption per bed	3552.6	2347.8	3360.5	3884.1	3288.2	3139.0	5342.7	4878.7	4026.4
Heating consumption per room	6818.7	4764.7	6374.5	7068.7	5752.8	5838.1	10018.0	9390.7	7383.0
Total energy consumption in kWh	1742767.0	1121895.0	1857432.3	1302919.5	897566.0	1236605.7	1026429.8	761781.0	950417.5
Energy consumption per guest night	35.0	26.3	27.6	34.9	26.8	25.7	46.2	39.2	33.8
Energy consumption per room night	53.7	39.4	42.0	50.7	38.8	37.6	68.3	61.4	47.1
Energy consumption per bed	6005.3	4077.5	4772.0	5716.2	4464.3	4106.0	7626.4	7234.4	4937.2
Energy consumption per room	11562.8	7996.6	9149.5	10423.9	8371.0	7770.9	14187.8	14283.4	8623.0
Total water consumption in '000 liter	9914.7	6914.0	10224.5	7451.3	4378.0	10954.0	5758.3	3657.0	6126.6
Water consumption per guest night in liter	206.3	154.2	191.7	192.9	142.9	215.1	241.5	167.4	220.1
Water consumption per room night in liter	316.4	231.2	294.1	281.3	197.4	332.0	360.7	256.3	316.0
Water consumption per bed in '000 liter	36	25	33	33	24	38	43	33	42
Water consumption per room in '000 liter	69.0	49.0	61.1	60.2	44.6	74.3	80.3	65.1	75.4

Table 42: Descriptive Statistics Building Age
Source: Author's own data

Therefore, it can be concluded that water consumption is less affected by building age as water efficiency measures can be retrofitted more easily than to increase, e.g., heating efficiency. When analyzing a cluster of hotels built before and after 2018, the contrast becomes even more pronounced. A comparison reveals that the EUPGN is 61% lower in properties constructed after 2018, indicating a substantial disparity in energy efficiency linked to building age. Furthermore, water consumption per room night is also significantly lower with 318.2 liters (<2018) compared to 216.3 liters (>2018). Therefore, the result of the study of AlFaris et al. (2016) must be agreed on that younger hotels are generally more resource-efficient than older hotels. This result is unsurprising, as newer hotels are typically built with newer construction materials and often possess an environmental label such as DGNB or LEED. Though, it has to be acknowledged that other attributes such as quality level or location may interfere with results.

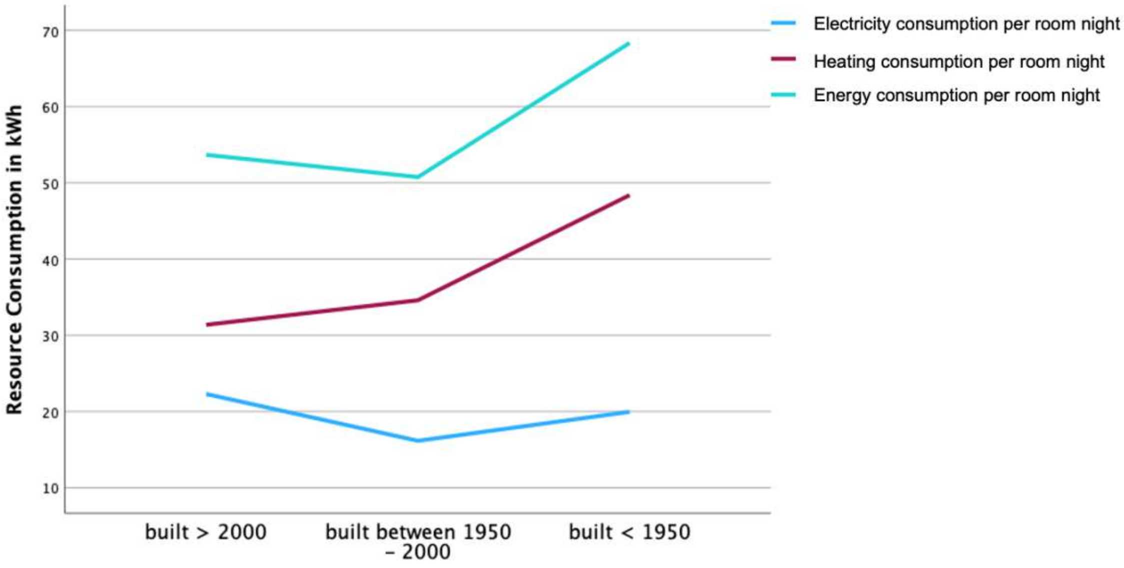

Figure 24: Building Age Comparison Electricity, Heating, Energy Consumption
Source: Author's own data
Please note: The graph represents an extrapolation derived from observed data patterns

Air-Conditioning Consumption Analysis

	Air conditioning					
	non-existent			existent		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Building Year	1973	1993	62	1988	2004	55
Number of floors	4	4	2	6	5	5
Number of restaurants	1	1	1	1	1	1
Number of rooms	115	101	69	145	137	82
Number of beds	215	192	131	275	256	152
Total guest nights	36560.2	31679.7	25419.2	49874.3	46282.0	30299.9
Total room nights	24541.2	21500.3	16919.4	32869.9	29907.3	20201.1
Av. room occupancy	58.9	61.6	13.9	62.8	64.4	13.2
Av. rate in Euro	107.2	85.0	58.4	126.9	107.8	72.5
Av. REVPAR in Euro	57.3	48.1	45.3	78.0	63.5	57.6
Total electricity consumption in kWh	431016.9	232484.5	521101.6	695407.2	472241.0	806024.4
Electricity consumption per guest night	11.7	8.2	10.7	14.4	10.4	12.8
Electricity consumption per room night	17.4	12.5	16.0	21.5	16.1	18.2
Electricity consumption per bed	1896.1	1357.0	1633.9	2499.1	1963.9	2028.6
Electricity consumption per room	3527.2	2405.8	3083.1	4669.7	3899.6	3572.4

Table 43: Descriptive Statistics Air-Conditioning
Source: Author's own data

Another factor highlighted by the literature that affects electricity consumption is the existence of air-conditioning (Graci and Dodds, 2008; Huang et al., 2015; Lanka Udawatta et al., 2010; Priyadarsini et al., 2009; Xuchao et al., 2010; Yao et al., 2015). In total, 44.7% of the sample possesses an air-conditioning (133 hotels). Descriptive statistics (Table 43) illustrate that while the hotel size and occupancy level are almost similar, hotels with air-conditioning can generate a higher room rate (107.2 Euro non-air-conditioning, 126.9 Euro air-conditioning). Nevertheless, this finding may also be correlated with the quality level of a hotel, as higher-class hotels typically possess air-conditioning in the German and Austrian hotel industry. Regarding resource consumption, while water consumption is not affected by the existence of air-conditioning, an effect can be seen with electricity consumption. There, the consumption per room night is slightly affected, resulting in an average EUPRN of 17.4 kWh (no air-conditioning) compared to 21.5 kWh (air-conditioning). This result complements the study of Lanka Udawatta et al. (2010) and Yao et al. (2015) that variances may be higher in regions with more significant weather differences and higher usage of air-conditioning.

6.2.1.5. Environmental Hardware Retrofitting

Hardware characteristics influencing energy efficiency are displayed in Table 44. Generally, it is found that the higher the hotel category, the more energy-efficient actions are installed. The analysis reveals that easily implementable retrofitting measures have been adopted by the vast majority of hotels in the sample. These include the installation of LED lamps in guest rooms (96.7% of the total sample), low-energy televisions (79.7% of the total sample), motion detectors in indoor- (86.7% of the total sample) and outdoor areas (88.7% of the total sample), as well as shading systems on windows (99% of the total sample).

		Location											
		City				Countryside				Total			
		Star Rating				Star Rating				Star Rating			
		Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total
Building certification (DGNB, LEED)	existent	1.7%	5.4%	0.0%	3.6%	0.0%	1.0%	15.4%	1.9%	0.9%	2.9%	11.1%	2.7%
Low energy building	existent	3.3%	8.1%	0.0%	5.8%	4.2%	6.9%	15.4%	6.8%	3.7%	7.4%	11.1%	6.3%
Energy efficient building hull	existent	3.3%	8.1%	60.0%	7.9%	10.4%	24.8%	30.8%	21.0%	6.5%	17.7%	38.9%	15.0%
Energy efficient refurb of interior	existent	25.0%	20.3%	60.0%	23.7%	29.2%	43.6%	23.1%	37.7%	26.9%	33.7%	33.3%	31.2%
Roof insulation	existent	18.3%	24.3%	60.0%	23.0%	27.1%	34.7%	69.2%	35.2%	22.2%	30.3%	66.7%	29.6%
Cellar insulation	existent	5.0%	9.5%	20.0%	7.9%	2.1%	11.9%	30.8%	10.5%	3.7%	10.9%	27.8%	9.3%
Insulated glazing	existent	16.7%	31.1%	20.0%	24.5%	31.3%	53.5%	76.9%	48.8%	23.1%	44.0%	61.1%	37.5%
Insulated heating cables	existent	88.3%	97.3%	100.0%	93.5%	95.8%	99.0%	100.0%	98.1%	91.7%	98.3%	100%	96.0%
Condensing boilers with heat recovery	existent	13.3%	29.7%	40.0%	23.0%	12.5%	39.6%	38.5%	31.5%	13.0%	35.4%	38.9%	27.6%
Air treatment with heat recovery	existent	16.7%	68.9%	60.0%	46.0%	16.7%	62.4%	53.8%	48.1%	16.7%	65.1%	55.6%	47.2%
LED lamps in hotel 30% – 60 %	existent	11.7%	14.9%	0.0%	12.9%	25.0%	19.8%	0.0%	19.8%	17.6%	17.7%	0.0%	16.6%
LED lamps in hotel 60% – 90%	existent	38.3%	32.4%	40.0%	35.3%	39.6%	32.7%	38.5%	35.2%	38.9%	32.6%	38.9%	35.2%
LED lamps > 90%	existent	48.3%	52.7%	60.0%	51.1%	35.4%	47.5%	61.5%	45.1%	42.6%	49.7%	61.1%	47.8%
Motion detectors in outdoor areas	existent	80.0%	91.9%	100.0%	87.1%	85.4%	92.1%	92.3%	90.1%	82.4%	92.0%	94.4%	88.7%
Motion detectors in indoor areas	existent	80.0%	93.2%	60.0%	86.3%	85.4%	87.1%	92.3%	87.0%	82.4%	89.7%	83.3%	86.7%
In room: LED lamps	existent	91.7%	98.6%	100.0%	95.7%	95.8%	98.0%	100.0%	97.5%	93.5%	98.3%	100%	96.7%
In room: low energy television	existent	56.7%	93.2%	60.0%	76.3%	66.7%	88.1%	100.0%	82.7%	61.1%	90.3%	88.9%	79.7%
In room: shading system on windows	existent	98.3%	100.0%	100.0%	99.3%	100.0%	98.0%	100.0%	98.8%	99.1%	98.9%	100%	99.0%
In room: energy efficient minibars	existent	5.0%	17.6%	60.0%	13.7%	16.7%	11.9%	15.4%	13.6%	10.2%	14.3%	27.8%	13.6%
In room: minibar	existent	21.7%	64.9%	60.0%	46.0%	41.7%	48.5%	76.9%	48.8%	30.6%	55.4%	72.2%	47.5%
Centralised drinks/snack machines	existent	51.7%	47.3%	40.0%	48.9%	43.8%	40.6%	15.4%	39.5%	48.1%	43.4%	22.2%	43.9%
In room: coffee machine	existent	33.3%	56.8%	100.0%	48.2%	45.8%	39.6%	53.8%	42.6%	38.9%	46.9%	66.7%	45.2%
HRMS	existent	23.3%	51.4%	0.0%	37.4%	12.5%	41.6%	46.2%	33.3%	18.5%	45.7%	33.3%	35.2%
HRMS connected to property system	existent	6.7%	13.5%	20.0%	10.8%	0.0%	10.9%	15.4%	8.0%	3.7%	12.0%	16.7%	9.3%
HRMS controlled by guest	existent	45.0%	78.4%	80.0%	64.0%	16.7%	52.5%	84.6%	44.4%	32.4%	63.4%	83.3%	53.5%

Table 44: Hardware Characteristics Energy-related
Source: Author's own data

More advanced retrofit measures, such as roof insulation (29.6% of the total sample), cellar insulation (9.3% of the total sample), and insulated glazing (37.5% of the total sample), are less prevalent and unevenly distributed across the dataset. These measures are not strongly influenced by location, quality level, or other dominant attributes. However, insulated heating cables are present in almost the whole sample (96%).

Regarding the percentage of LED lamps in the hotel, it is found that the higher the star rating of the hotel, the more LED lamps are installed in the respective property (LED lamps >90% 5-star 61.1%). Especially in city midscale properties, most hotels have no minibar in the room (21.7%) compared to, e.g., luxury countryside hotels (76.9%). However, it is found that when there is no minibar, the hotels are equipped with centralized drinks/snack machines (43.9% of total sample). About 35% of hotels possess a multi-functional Hotel Room Management System (HRMS), such as temperature management when the room is unoccupied, a key card system for lighting, or an automatic shading system depending on the sun and wind. Of these hotels, only a third is connected to the property management system. A key card system with the main switch in the room is evident in 54% of the sample (variable HRMS controlled by guests), which gradually increases depending on the hotel's star rating.

While the green building certification rate is at 3% relatively low, 25% of countryside luxury properties are certified with LEED, DGNB. When tested against the age of the property, interestingly hotels built before 2018 only 1% possess a green building certification (out of 270 properties), hotels built after 2018 already 13% (out of 31 properties) are green certified by DGNB, Leeds or equivalent (see Figure 25). Furthermore, a building certification is generally more common in luxury hotels than in lower-quality categories. This highlights the increased demand for green certifications when hotels are newly built (DGNB, 2022).

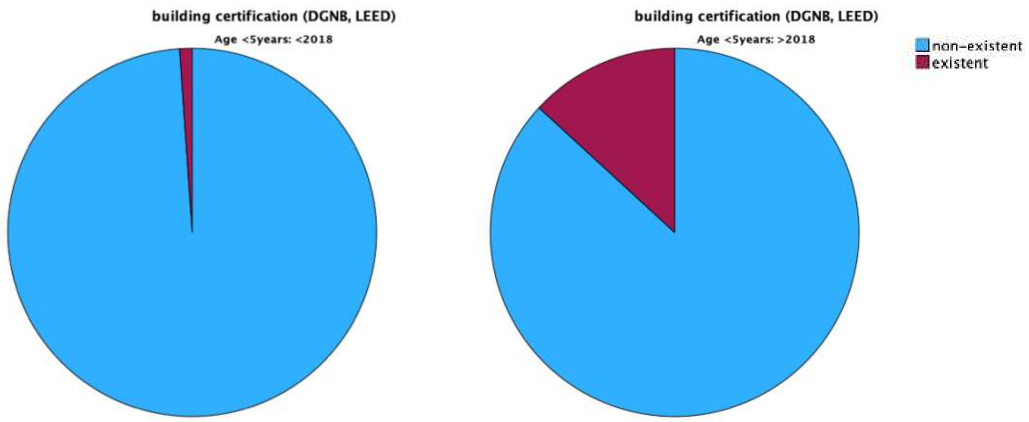

Figure 25: Green Building Certification Age Comparison
Source: Author's own data

Water efficiency is dependent on the appliances installed (Alhudaithi et al., 2022). Therefore, Table 45 illustrates the hardware characteristics relating to water efficiency efforts. Similar to energy hardware retrofitting, it is found that most hotels already installed easy-to-retrofit measures such as water flow limiters (91.7% of total sample), toilet flush limiters with stop functions (84.7% of total sample), water-efficient shower taps (86.7% of total sample), shower heads (86.7% of total sample), and urinals (84.1% of total sample). On average, about 40% of countryside hotels collect and use their rainwater. Furthermore, sensor technology in public areas is predominantly installed in more luxury hotels (61.1%), leaving room for improvement (46.5% of total sample).

		Location											
		City				Countryside				Total			
		Star Rating				Star Rating				Star Rating			
		Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total
Use of flow limiters	existent	91.7%	91.9%	100.0%	92.1%	85.4%	93.1%	100.0%	91.4%	88.9%	92.6%	100.0%	91.7%
Water efficient taps	existent	81.7%	93.2%	100.0%	88.5%	83.3%	84.2%	100.0%	85.2%	82.4%	88.0%	100.0%	86.7%
Water efficient toilet flush	existent	75.0%	87.8%	80.0%	82.0%	79.2%	90.1%	92.3%	87.0%	76.9%	89.1%	88.9%	84.7%
Water efficient shower heads	existent	83.3%	85.1%	60.0%	83.5%	89.6%	88.1%	100.0%	89.5%	86.1%	86.9%	88.9%	86.7%
Water efficient urinals	existent	80.0%	90.5%	100.0%	86.3%	72.9%	86.1%	84.6%	82.1%	76.9%	88.0%	88.9%	84.1%
Use of water fittings with sensor technology in public areas	existent	28.3%	56.8%	60.0%	44.6%	41.7%	49.5%	61.5%	48.1%	34.3%	52.6%	61.1%	46.5%
Toilet flush with stop function	existent	95.0%	93.2%	100.0%	94.2%	91.7%	96.0%	100.0%	95.1%	93.5%	94.9%	100.0%	94.7%
Central descaling system	existent	33.3%	63.5%	80.0%	51.1%	35.4%	45.5%	46.2%	42.6%	34.3%	53.1%	55.6%	46.5%
Automated irrigation systems	existent	5.0%	21.6%	100.0%	17.3%	2.1%	23.8%	53.8%	19.8%	3.7%	22.9%	66.7%	18.6%
Usage of rainwater	existent	33.3%	36.5%	20.0%	34.5%	25.0%	40.6%	69.2%	38.3%	29.6%	38.9%	55.6%	36.5%
Water recycling system	existent	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	1.2%	0.0%	1.1%	0.0%	0.7%

Table 45: Hardware Characteristics Water-related
Source: Author's own data

Dissimilar to the findings of studies highlighting the importance of grey water (Gössling, 2015), water recycling systems to convert grey water are not evident across the German and Austrian hotel markets (1% of the total sample). This complements the qualitative interview phase findings that grey water usage needs more attention in the German and Austrian hotel industry. Another resource consumption factor stated in the literature is the irrigation of gardens (Alhudaithi et al., 2022; Deyà Tortella and Tirado, 2011). Therefore, the share of automated irrigation systems is tracked, especially in countryside hotels where all hotels are assumed to possess a garden. Interestingly, only 18.6% of those hotels are equipped with an automated system, leaving room for further improvement.

6.2.1.6. Data Set Characteristics External Factors

The location variable illustrated in Table 46 is clustered in city (139 hotels) and countryside hotels (162 hotels). Whereas the latter are located in more rural areas focusing on the leisure-driven guest, city hotels are located in urban areas focusing on the business clientele. Countryside hotels generally possess a larger service spectrum with wellness areas and a multitude of restaurants or sporting facilities. When analyzing the location variable, it is evident countryside hotels are generally older than hotels located in city locations (1974 and 1987, respectively). Furthermore, city-located rooms are larger (147 rooms) than hotels in more rural areas (112 rooms).

	Location					
	City			Countryside		
	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Building Year	1987	1999	45	1974	1995	69
Number of floors	6	5	5	4	4	2
Number of restaurants	1	1	1	1	1	1
Number of rooms	147	130	80	112	101	69
Number of beds	280	250	157	208	197	122
Total guest nights	51201.1	45917.5	33018.5	34928.7	33278.7	21145.9
Total room nights	33717.5	29532.9	21133.7	23505.4	21731.4	15238.4
Av. room occupancy	63.4	64.4	13.9	58.2	60.0	13.2
Av. rate in Euro	102.4	85.0	46.0	127.5	105.1	77.0
Av. REVPAR in Euro	62.5	53.2	37.3	69.8	52.2	61.9
Total electricity consumption in kWh	564858.4	374217.0	665885.9	533238.7	324839.0	682659.8
Electricity consumption per guest night	11.0	7.9	10.4	14.5	10.4	12.6
Electricity consumption per room night	16.5	11.9	15.1	21.5	15.5	18.4
Electricity consumption per bed	1913.2	1352.6	1543.1	2376.5	1740.4	2042.1
Electricity consumption per room	3582.9	2632.4	2862.5	4417.4	3402.0	3684.9
Total heating consumption in kWh	737433.9	583625.0	611714.2	1043045.0	651115.0	1245286.2
Heating consumption per guest night	16.4	14.7	12.0	29.6	25.0	24.3
Heating consumption per room night	24.4	20.9	18.0	44.2	38.0	36.0
Heating consumption per bed	2857.2	2420.2	2057.9	4860.6	4019.6	3993.5
Heating consumption per room	5299.0	4758.6	3775.2	9104.3	7445.2	7484.5
Total energy consumption in kWh	1302292.3	1015146.0	1170868.3	1576283.7	1028187.5	1755156.1
Energy consumption per guest night	27.4	22.8	18.6	44.1	35.6	31.9
Energy consumption per room night	40.9	32.8	27.5	65.7	55.6	46.9
Energy consumption per bed	4719.6	3862.8	2953.4	7254.3	5960.5	5269.5
Energy consumption per room	8764.4	6947.1	5439.9	13632.7	11434.7	9968.5
Total water consumption in '000 liter	8487.4	5749.0	9875.6	8119.6	4988.5	10562.8
Water consumption per guest night in liter	168.3	136.9	151.4	236.1	161.3	239.3
Water consumption per room night in liter	251.2	201.1	221.7	353.6	228.5	370.4
Water consumption per bed in '000 liter	31	25	28	39	26	41
Water consumption per room in '000 liter	57.6	48.0	51.1	74.1	47.7	81.1

Table 46: Descriptive Statistics Location
Source: Author's own data

Resource consumption figures differentiate strongly, indicating that city hotels are more efficient than countryside hotels (EUPGN 27.4 kWh in city hotels, 44.1 kWh in countryside hotels). Interestingly, electricity consumption per guest night (11.0 kWh in city hotels, 14.5 kWh in countryside hotels, +31.8%) is less affected than heating consumption per guest night (16.4 kWh in city hotels, 29.6 kWh in countryside hotels, +80.4%), indicating that rural hotels need more heating due to building architecture and number of outlets (e.g., spa areas, restaurants). The same pattern is evident when analyzing water consumption (WUPGN 168.3 liters in city hotels, 236.1 liters in countryside hotels), indicating that more resource-extensive outlets exist in countryside hotels. Even though countryside hotels are less energy efficient due to their service level and scope, this result is contrary to the analyzed total sample of existing audits (see Chapter 2.4.5.2).

6.2.1.7. Laundry Outsourcing

As emphasized by various scholars, it is essential to differentiate the degree of outsourcing of laundry facilities (Alhudaithi et al., 2022; Bohdanowicz and Martinac, 2007; Deng, 2003; Ricaurte, 2011). In the analyzed sample of 160 hotels that provided data on laundry characteristics, the majority of the sample possesses outsourced laundry (132 hotels). When analyzing Table 47, a pattern can be observed in city hotels, that used outsourced laundry facilities are to be in close proximity to the hotel site (41.4% laundry location <10km). The outsourced laundry location is generally farther away as countryside hotels are located in more rural areas (29.3% laundry location <30km). Interestingly, 65% of the outsourced laundries are environmentally certified.

		Location											
		City				Countryside				Total			
		Star Rating				Star Rating				Star Rating			
		Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total
Laundry in-house	existent	3.7%	9.8%	0.0%	7.1%	12.5%	27.4%	46.2%	26.3%	7.8%	20.4%	40.0%	18.3%
Laundry outsourced <10km	existent	29.6%	48.8%	50.0%	41.4%	20.8%	17.7%	23.1%	19.2%	25.5%	30.1%	26.7%	28.4%
Laundry outsourced <20km	existent	51.9%	26.8%	0.0%	35.7%	33.3%	25.8%	7.7%	25.3%	43.1%	26.2%	6.7%	29.6%
Laundry outsourced <30km	existent	14.8%	14.6%	50.0%	15.7%	33.3%	29.0%	23.1%	29.3%	23.5%	23.3%	26.7%	23.7%
Laundry sustainability certification	existent	88.9%	70.7%	100.0%	78.6%	58.3%	54.8%	53.8%	55.6%	74.5%	61.2%	60.0%	65.1%

	not outsourced			outsourced		
a	Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
Total energy consumption in kWh	1460689.9	670499.0	1688181.1	1291177.4	1005548.5	1279356.0
Energy consumption per guest night	48.8	43.0	31.5	34.9	25.6	29.0
Energy consumption per room night	71.6	64.3	44.6	52.1	36.1	42.5
Energy consumption per bed	8753.0	8083.5	5456.2	5745.4	4374.4	4319.5
Energy consumption per room	16166.1	14944.0	10212.5	10839.6	7725.6	8375.5
Total water consumption in '000 liter	9148.1	3641.0	11234.8	6307.3	5285.0	5423.6
Water consumption per guest night in liter	285.6	237.2	242.1	170.8	142.9	135.2
Water consumption per room night in liter	423.9	308.9	367.7	256.7	219.0	198.3
Water consumption per bed in '000 liter	52	38	44	29	25	22
Water consumption per room in '000 liter	97.7	73.0	87.5	55.0	47.5	41.7

Table 47: Laundry Outsourcing Comparison[30]
Source: Author's own data

When comparing resource consumption figures of hotels with an in-house laundry (28 hotels) and outsourced laundry (132 hotels) an influence in energy (EUPGN 48.8 kWh non-outsourced vs. 34.9 kWh outsourced, +39.8%) and especially in water consumption (WUPGN 285.6 liters non-outsourced vs. 170.8 liters outsourced, +67.2%) is observable. This pattern is similar to the study of Bohdanowicz and Martinac (2007). As a result, the degree of laundry outsourcing strongly influences resource consumption. However, this result may be distorted because higher-class hotels more often possess an in-house laundry (e.g., 46% of countryside hotels are 5-star hotels).

[30] Please note: In total, 160 hotels of the sample have provided information about laundry outsourcing. Therefore, in this section, a smaller sample is the basis for analysis.

6.2.1.8. Energy Mix

The energy mix refers to the primary energy sources needed to operate a hotel. Although the dataset provided consumption data, the decomposition in major end-users (e.g., energy consumption in the rooms department) is not evident. Electricity powers HVAC, lighting, escalators, and other operating appliances. Heating refers to liquified gas, which is used for heating boilers for hot water, heating systems as well as and cooking (e.g., gas stoves). As found in studies in other geographical settings (Priyadarsini et al., 2009), diesel is not a primary fuel source in Central European hotels. Nevertheless, some hotels are equipped with an emergency generator for evacuation lighting, which operates solely during test trials conducted as part of the annual maintenance process.

	Location											
	City				Countryside				Total			
	Star Rating				Star Rating				Star Rating			
	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total
Electricity in %	34.29	44.84	54.40	40.63	29.02	39.19	43.24	36.50	31.95	41.58	46.34	38.41
Heating in %	65.71	55.16	45.60	59.37	70.98	60.81	56.76	63.50	68.05	58.42	53.66	61.59

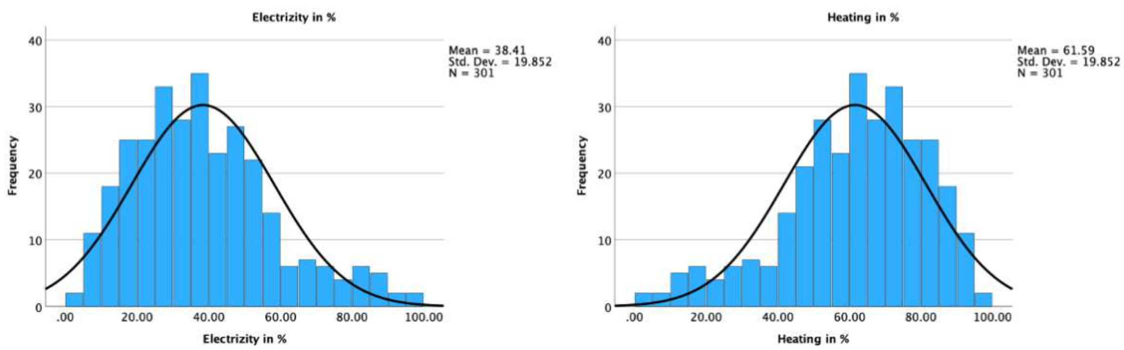

Figure 26: Share of Electricity for City and Countryside Hotels
Source: Author's own data

A total mean electricity to total energy ratio of 38.4% and a mean heating to total energy ratio of 61.5% are found (Figure 26). When analyzing the location variable, it was found that the electricity ratio is generally higher in city hotels (40.6%) than in countryside locations (36.5%). Similar to the analysis in Chapter 6.2.1.6, one could argue that countryside hotels need more resources to heat the buildings in rural locations. Within the star rating, the ratio of electricity generally increases when the quality level increases (Midscale 32%, Upscale 42%, Luxury 43%). This may be due to the fact that 3-star hotels generally are less service-intensive and do not possess resource intensive equipment such as air-conditioning systems or minibars.

6.2.1.9. Renewable Energy

As the literature indicates, buying green electricity has enormous potential for GHG emission reduction. Therefore, the share of green electricity in the data set is illustrated in Table 48. Approximately 39.5% of the audited hotels procure the entirety of their electricity from renewable sources, while an additional 10% source at least 75% of their electricity from green energy. In contrast, nearly 50% of the hotels do not purchase any electricity from renewable sources, highlighting a substantial gap in the sector's adoption of sustainable energy practices. This disparity indicates considerable potential for future improvements in environmental performance within the German and Austrian hospitality industry.

		Location											
		City Star Rating				Countryside Star Rating				Total Star Rating			
		Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total
Green Energy	existent	30.0%	47.3%	60.0%	40.3%	45.8%	56.4%	92.3%	56.2%	37.0%	52.6%	83.3%	48.8%
Green energy 75% of total consumption	existent	1.7%	10.8%	40.0%	7.9%	2.1%	13.9%	30.8%	11.7%	1.9%	12.6%	33.3%	10.0%
Green energy 100% of total consumption	existent	28.3%	37.8%	20.0%	33.1%	43.8%	43.6%	61.5%	45.1%	35.2%	41.1%	50.0%	39.5%

Table 48: Green Electricity Share
Source: Author's own data

Alongside green electricity, renewable alternative electricity and heating options must be considered (Table 49). Regarding other renewable energy options, the data set shows that hotels possess either solar panels (5%) or photovoltaic panels (11.6%). Nevertheless, it has to be acknowledged that the size of panels or monthly electricity production is not listed. Possibly caused by limitations in installation surface, this source of electricity production is far more developed in countryside hotels (8% solar, 18.5% photovoltaic). Water (1.3% of the total sample), wind (0% of the total sample), or bioenergy (0.7% of the total sample) production plants on site are less developed in the sample. Regarding district heating as main heating source, the implementation is far more developed in urban regions (38.8% of city hotels) rather than in rural areas (9.9% of countryside hotels). This result is not unexpected, as district heating infrastructure is primarily concentrated in urban areas. Other forms of heating, such as wood pellets and biogas (3.0% each of the total sample), are less present. Therefore, most of the sampled hotels rely on conventional heating methods using gas or oil.

		Location											
		City Star Rating				Countryside Star Rating				Total Star Rating			
		Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total
Electricity solar	existent	1.7%	1.4%	0.0%	1.4%	8.3%	7.9%	7.7%	8.0%	4.6%	5.1%	5.6%	5.0%
Electricity photovoltaic	existent	3.3%	1.4%	40.0%	3.6%	12.5%	18.8%	38.5%	18.5%	7.4%	11.4%	38.9%	11.6%
Electricity water power plant	existent	0.0%	1.4%	0.0%	0.7%	0.0%	3.0%	0.0%	1.9%	0.0%	2.3%	0.0%	1.3%
Electricity wind power plant	existent	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electricity bioenergy power plant	existent	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.4%	1.2%	0.0%	0.0%	11.1%	0.7%
Heating own heat exchanger	existent	23.3%	43.2%	0.0%	33.1%	10.4%	39.6%	69.2%	33.3%	17.6%	41.1%	50.0%	33.2%
Heating wood pellets	existent	0.0%	0.0%	0.0%	0.0%	0.0%	7.9%	7.7%	5.6%	0.0%	4.6%	5.6%	3.0%
Heating bio gas	existent	0.0%	5.4%	0.0%	2.9%	2.1%	3.0%	7.7%	3.1%	0.9%	4.0%	5.6%	3.0%
Heating district heating	existent	30.0%	45.9%	40.0%	38.8%	6.3%	10.9%	15.4%	9.9%	19.4%	25.7%	22.2%	23.3%
Heating with waste water	existent	0.0%	0.0%	0.0%	0.0%	0.0%	3.0%	0.0%	1.9%	0.0%	1.7%	0.0%	1.0%
Waste power plant	existent	3.3%	9.5%	0.0%	6.5%	8.3%	29.7%	46.2%	24.7%	5.6%	21.1%	33.3%	16.3%

Table 49: Renewable Electricity and Heating Share
Source: Author's own data

6.2.1.10. Waste Benchmarking Practices

Dissimilar to other studies measuring waste in kg, i.e., collecting absolute waste consumption figures (Camilleri-Fenech et al., 2020; Papargyropoulou et al., 2016; Roselló-Batle et al., 2010), the data set consisted of dichotomous variables about basic information of waste documentation and separation behavior (Table 50).

		Location											
		City Star Rating				Countryside Star Rating				Total Star Rating			
		Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total	Midscale (3 star)	Upscale (4 star)	Luxury (5 star)	Total
Waste consumption tracked	existent	100.0%	98.6%	100%	99.3%	97.9%	100.0%	100.0%	99.4%	99.1%	99.4%	100.0%	99.3%
Documentation of monthly waste consumption	existent	73.3%	78.4%	40.0%	74.8%	41.7%	61.4%	92.3%	58.0%	59.3%	68.6%	77.8%	65.8%
Documentation of yearly waste consumption	existent	25.0%	21.6%	60.0%	24.5%	56.3%	33.7%	7.7%	38.3%	38.9%	28.6%	22.2%	31.9%
Waste separation system in hotel room	existent	3.3%	9.5%	40.0%	7.9%	4.2%	9.9%	15.4%	8.6%	3.7%	9.7%	22.2%	8.3%
Waste separation system in public areas	existent	6.7%	24.3%	0.0%	15.8%	8.3%	22.8%	38.5%	19.8%	7.4%	23.4%	27.8%	17.9%
Waste separation system in personnel areas	existent	56.7%	97.3%	100%	79.9%	83.3%	95.0%	100.0%	92.0%	68.5%	96.0%	100.0%	86.4%
Waste separation by housekeeping	existent	88.3%	91.9%	100%	90.6%	95.8%	92.1%	100.0%	93.8%	91.7%	92.0%	100.0%	92.4%
Zero waste breakfast	existent	5.0%	40.5%	60.0%	25.9%	16.7%	43.6%	53.8%	36.4%	10.2%	42.3%	55.6%	31.6%

Table 50: Waste Consumption Variables
Source: Author's own data

Although almost all hotels track their waste consumption monthly (65.8% of all hotels) or yearly (31.9% of all hotels), the specific implications of the kind of tracking or the details of the waste tracking process are not further defined. Whereas waste separation systems are predominantly not installed in hotel rooms (8.3% existent) or public areas (17.9% existent), in back-of-house areas, these systems are evident (86.4% existent). When it comes to the operational process, it is found that the housekeeping department is predominantly in charge of waste separation (92.4% of all hotels). A zero-waste breakfast is offered more in countryside hotels (36.4%) than in city hotels (25.9%). As a result, it can be seen that hotels are increasingly aware of waste tracking and separation, but no absolute figures are evident. This further aligns with scholars' views, and the qualitative interview process highlights the necessity of a stringent waste consumption tracking process.

6.2.1. Descriptive Statistics Comparison with SLR

When comparing the sample size to existing studies outlined in the SLR section, as displayed in Table 51, this research ranks as the third-largest academic study in the field of hotel resource consumption benchmarking and about six times larger than the average sample size of previous scientific benchmarking audits (51 hotels on average). Furthermore, it is the first study to analyze an extensive data set of hotel resource consumption in the German and Austrian hotel industry and Central Europe.

Source	Year	Research Method	Sample Size	Location of sample	Research Field	Quality level of sample hotels	City / Vacation Hotel
Becken, S., McLennan, C.	2017	Quantitative	821	Globally	Energy, Water, Waste	1, 2, 3, 4, 5	City and Vacation
Alkhalaf H., Yan W.	2018	Quantitative	339	Japan	Energy	Not stated	Not stated
This Study		Quantitative	301	Germany, Austria	Energy, Water, Waste	3, 4, 5	City and Vacation
Sheng Y., Miao Z., Zhang J., Lin X., Ma H.	2018	Quantitative	295	China	Energy	5 star	City and Vacation
Wang, J.C.	2012	Quantitative	200	Taiwan	Energy	1, 2, 3, 4, 5	City and Vacation
Deyà Tortella, B., Tirado, D.	2011	Quantitative	196	Spain	Water	1, 2, 3, 4, 5	Vacation
Bohdanowicz, P., Martinac, I.	2007	Quantitative	184	Europe	Energy, Water	3, 4	City and Vacation
Santamouris, M., Balaras, C.A., Dascalaki, E.	1997	Quantitative	158	Greece	Energy	1, 2, 3, 4, 5	City
Paulusch K., Sander K., Weber C.	2000	Quantitative	140	Germany	Energy	1, 2, 3, 4, 5	City and Vacation
Mechri H.E., Amara S.	2021	Quantitative	137	Tunisia	Energy, Water	3, 4, 5	Vacation
Farrou, I., Kolokotroni, M., Santamouris, M.	2012	Quantitative	90	Greece	Energy	Not stated	City and Vacation
Hsien-te L., Chia-ju Y.	2021	Quantitative	89	Taiwan	Energy	2, 3, 4	not stated
Chedwal, R., Mathur, J., Agarwal, G.D., Dhaka, S.	2015	Quantitative	79	India	Energy	Not stated	City
Wickramasinghe K.	2019	Quantitative	78	Sri Lanka	Energy, Waste, Water	Not stated	City and Vacation

Table 51: Sample Size Comparison with Previous Studies
Source: Author's own data

In comparison to the consumption audits of other studies (see Table 52), the EUPGN of 36.4 kWh in this study aligns closely with the findings of European audits conducted by Coles et al. (2016), which analyzed 29 hotels in the UK and found an EUPGN of 32.6 kWh. Similarly, Díaz Pérez et al. (2019) reported an EUPGN of 22.1 kWh based on their study of 12 hotels in Spain..

Source	Year	Research Method	Sample Size	Location of sample	EUPGN	Quality level of sample hotels	City / Vacation Hotel
Lu, S., Wei, S., Zhang, K., Kong, X., Wu, W.	2013	Quantitative	27	China	317.7	4, 5	City
Papageorgiou G., Efstathiades A., Nicolaou N.	2018	Qualitative	not stated	Cyprus	170.0	Not stated	Not stated
Debnath S.	2015	Qualitative	2	India	103.3	3, 4, 5	City
Becken, S., McLennan, C.	2017	Quantitative	821	Globally	64.8	1, 2, 3, 4, 5	City and Vacation
Cunha, F.O., Oliveira, A.C.	2020	Qualitative	1	Portugal	59.0	4 star	Vacation
Wang, J.C.	2012	Quantitative	200	Taiwan	53.3	1, 2, 3, 4, 5	City and Vacation
Warnken, J., Bradley, M., Guilding, C.	2005	Mixed	16	Australia	39.7	3, 4, 5	Vacation
This Study		Quantitative	301	Germany, Austria	36.4	3, 4, 5	City and Vacation
Coles, T., Dinan, C., Warren, N.	2016	Quantitative	29	UK	32.6	3, 4	City and Vacation
Meade B., Pringle J.	2001	Quantitative	5	Jamaica	30.7	Not stated	Vacation
Díaz Pérez, F.J., Chinarro, D., Guardiola Mouhaffel, A.	2019	Quantitative	12	Spain	22.1	1, 2, 3, 4, 5	Vacation
Beccali, M., La Gennusa, M., Lo Coco, L., Rizzo, G.	2009	Quantitative	4	Italy	18.0	1, 2, 3, 4, 5	City and Vacation
Bohdanowicz, P., Martinac, I.	2007	Quantitative	184	Europe	16.4	3, 4	City and Vacation
Puig, R., Kiliç, E., Navarro, A., Albertí	2017	Quantitative	14	Spain	12.4	2, 3, 4, 5	Vacation

Table 52: EUPGN Audit Comparison with Previous Study Results
Source: Author's own data

Regarding water consumption (see Table 53), the WUPGN of 204.7 liters in this study is comparable to the results of Deyà Tortella and Tirado (2011), who analyzed 196 hotels in Spain and found a WUPGN of 156.6 liters. Furthermore, the result closely aligns with the reported WUPGN of 170 liters by the Scandic Hotel Group, which operates predominantly within the European market (see Table 17). This comparison is particularly noteworthy, as regions with higher water consumption, such as those with water-intensive amenities, are expected to report higher usage.

Source	Year	Research Method	Sample Size	Location of Sample	WUPGN	Quality Level	City / Vacation Hotel
Charara, N., Cashman, A., Bonnell, R., Gehr, R.	2011	Quantitative	21	Barbados	839.0	Not stated	Vacation
Gössling, S.	2001	Quantitative	28	Tansania	685.0	Not stated	Vacation
Khemiri, A; Hassairi, M	2005	Qualitative	1	Tunisia	670.7	3 star	City
Warnken, J., Bradley, M., Guilding, C.	2005	Mixed	16	Australia	630.1	3, 4, 5	Vacation
Hof, A., Schmitt, T.	2011	Quantitative	not stated	Spain	606.1	Not stated	Vacation
Becken, S., McLennan, C.	2017	Quantitative	821	Globally	571.1	1, 2, 3, 4, 5	City and Vacation
Klontza, E.E., Kampragkou, E., Ververidis, K.	2016	Quantitative	8	Greece	495.0	3 star	Vacation
Lootvoet, M., Roddier-Quefelec, C.	2009	Quantitative	not stated	Israel, Jordan, Morocco, Tunisia	466.0	Not stated	Vacation
Cunha, F.O., Oliveira, A.C.	2020	Qualitative	1	Portugal	458.0	4 star	Vacation
Gautam, S., Ahmed, S., Ahmed, K., Haleem, A.	2016	Quantitative	36	India	400.0	5 star	City
Debnath S.	2015	Qualitative	2	India	387.7	3, 4, 5	City
Ruiz-Rosa I., Antonova N., Mendoza-Jimenez J.	2022	Mixed	70	Spain	366.8	1, 2, 3, 4, 5	Vacation
Ratjen, G.	2016	not stated	not stated	Germany	356.8	2, 3, 4, 5	Not stated
Gössling, S.	2015	Qualitative	3	Greece	317.0	4, 5	Vacation
Puig, R., Kiliç, E., Navarro, A., Albertí	2017	Quantitative	14	Spain	315.5	2, 3, 4, 5	Vacation
Díaz Pérez, F.J., Chinarro, D., Guardiola Mouhaffel, A.	2019	Quantitative	12	Spain	295.6	1, 2, 3, 4, 5	Vacation
Rico-Amoros, A.M., Olcina-Cantos, J., Sauri, D.	2009	not stated	not stated	Spain	287.6	1, 2, 3, 4	Vacation
Bohdanowicz, P., Martinac, I.	2007	Quantitative	184	Europe	278.5	3, 4	City and Vacation
Meade B., Pringle J.	2001	Quantitative	5	Jamaica	268.8	Not stated	Vacation
Barberan, R; Egea, P; Gracia-de-Renteria, P; Salvador, M	2013	Mixed	1	Spain	252.0	4 star	City
Gabarda-Mallorquí, A., Garcia, X., Ribas, A.	2017	Qualitative	35	Spain	251.0	1, 2, 3, 4, 5	Vacation
This study		Quantitative	301	Germany, Austria	204.7	3, 4, 5	City and Vacation
Deyà Tortella, B., Tirado, D.	2011	Quantitative	196	Spain	156.6	1, 2, 3, 4, 5	Vacation
Styles D., Schoenberger H., Galvez-Martos J.L.	2015	Quantitative	2	not stated	140.0	3 star	Not stated
Cobacho, R., Arregui, F., Parra, J.C., Cabrera, E.,	2005	Qualitative	1	Spain	83.0	4 star	Not stated

Table 53: WUPGN Audit Comparison with Previous Study Results
Source: Author's own data

Moreover, the electricity to total energy ratio differentiates considerably from other academic study findings (Table 54). For example, in the study of Bohdanowicz and Martinac (2007) 184 chain-affiliated hotels across Europe were analyzed. An electricity to total energy ratio of 49% was found. When comparing other parts of Europe, such as the study of Cunha and Oliveira (2020) in Portugal with 81% electricity to total energy ratio or the study of Santiago (2021) in Spain with 80% electricity to total energy ratio are similar to studies in Singapore (Xuchao et al., 2010), Taiwan (Wang, 2012), and China (Lu et al., 2013). When analyzing the table, the electricity ratio found in this study has several reasons. First and foremost, in Asian countries (Huang et al., 2015;

Xuchao et al., 2010), heating is not done with equipment needing electricity (e.g., air-conditioning, electric radiator), rather than with gas in the German and Austrian hotel industry. Hotels in the sample are only rarely heated with electricity through air-conditioning (2 hotels). Second, humid and warm regions need more electricity resources for HVAC, possessing sometimes oversized cooling units (Sheng et al., 2018). Third, the study sample is mainly located in the more resource-efficient 3- and 4-star sectors; other studies are often using samples in the 4- and 5-star sectors.

Source	Year	Research Method	Sample Size	Location of sample	Electricity in %	Quality level of sample hotels	City / Vacation Hotel
Xuchao W., Priyadarsini R., Siew Eang L.	2010	Quantitative	29	Singapore	91	3, 4, 5	City
Beccali, M., La Gennusa, M., Lo Coco, L., Rizzo, G.	2009	Quantitative	4	Italy	90	1, 2, 3, 4, 5	City and Vacation
Onut, S; Soner, S	2006	Quantitative	32	Turkey	86	5 star	City
Trung, D.N., Kumar, S.	2005	Quantitative	37	Vietnam	85	3 star	City and Vacation
Wang, J.C.	2012	Quantitative	200	Taiwan	84	1, 2, 3, 4, 5	City and Vacation
Lu, S., Wei, S., Zhang, K., Kong, X., Wu, W.	2013	Quantitative	27	China	83	4, 5	City
Cunha, F.O., Oliveira, A.C.	2020	Qualitative	1	Portugal	81	4 star	Vacation
Santiago, D.E.	2021	Quantitative	6	Spain	80	2, 3, 4, 5	Vacation
Priyadarsini, R., Xuchao, W., Eang, L.S.	2009	Quantitative	29	Singapore	77	3, 4, 5	City
Yao, Z., Zhuang, Z., Gu, W.	2015	Mixed	45	China	75	3, 4, 5	City
Shiming, D., Burnett, J.	2002	Quantitative	16	Hong Kong	73	3, 4, 5	City
Deng, S.-M., Burnett, J.	2000	Quantitative	16	Hong Kong	73	3, 4, 5	City
Chan K.T., Lee R.H.K., Burnett J.	2003	Quantitative	26	Hong Kong	72	3, 4, 5	City
Becken, S., Frampton, C., Simmons, D.	2001	Quantitative	30	New Zealand	71	Not stated	City and Vacation
Deng, SM	2003	Quantitative	36	Hong Kong	68	4 star	City
Udawatta L., Perera A., Witharana S.	2010	Qualitative	1	Sri Lanka	68	5 star	Vacation
Bohdanowicz, P., Martinac, I.	2007	Quantitative	184	Europe	49	3, 4	City and Vacation
This Study	2024	Quantitative	301	Germany, Austria	38	3, 4, 5	City and Vacation

Table 54: Relative Electricity Share Comparison with Previous Study Findings
Source: Author's own data

To conclude, although resource audit results are generally in the range of previous scientific studies, it is found that the sample located in Germany and Austria consumes, on average, fewer resources than in other, predominantly humid and tropical regions. This may mainly be due to general climatic conditions and the fact that in those areas, close to 40% of total energy consumption is due to air-conditioning (Sheng et al., 2018).

Furthermore, as the data are derived from the GreenSign database, which comprises hotels that are actively engaged with sustainability practices, the resulting figures can be interpreted as representative of best practice benchmarks within the region.

6.2.2. Inferential Statistics

6.2.2.1. Test of Normality

To further perform inferential statistical testing, tests of normality, i.e., to test whether the data is consistent with the normal distribution, are a prerequisite to deciding whether parametrical or non-parametrical tests are done (Boslaugh and Watters, 2008). The normality analysis was performed for the following independent variables:

- Total energy consumption (*ttl_energy*)
- energy consumption per guest night (*energy_per_gn*)
- energy consumption per room night (*energy_per_rn*)
- energy consumption per bed (*energy_per_bed*)
- energy consumption per room (*energy_per_room*)

- Total water consumption (*ttl_water*)
- water consumption per guest night (*water_per_gn*)
- water consumption per room night (*water_per_rn*)
- water consumption per bed (*water_per_bed*)
- water consumption per room (*water_per_room*)

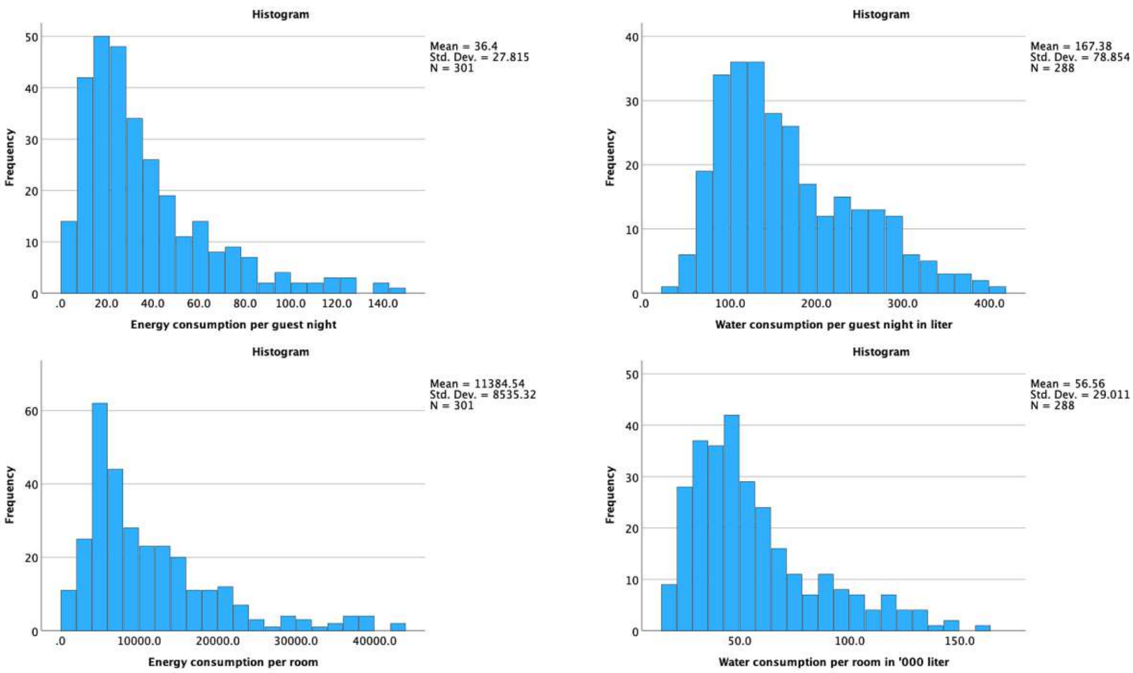

Figure 27: Histograms Energy and Water Consumption
Source: Author's own data

First, histograms are created to (Figure 27) to evaluate the data distribution. The data points are organized by consumption per guest night or room along the horizontal axis, while the frequency or count of data points falling within is plotted along the vertical axis. With a normal distribution, the histogram typically forms a bell-shaped curve, showcasing the central tendency and spread of the data (Mendenhall et al., 2020). When analyzing the figure below, it can be seen that the data is strongly formed towards the left side, concluding that it does not seem to be normally distributed. Second, two statistical tests are utilized to evaluate the normality of data further: the Shapiro-Wilk test and the Kolmogorov-Smirnov test. A Shapiro-Wilk p-value greater than 0.05 is indicative of normality (Koh and Ahad, 2020). Similarly, in the Kolmogorov-Smirnov test, a statistic value (p) less than 5% suggests significance, indicating a departure from normal distribution (Hair et al., 2024).

Energy Consumption

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total energy consumption in kWh	.203	301	<.001	.716	301	<.001
Energy consumption per guest night	.142	301	<.001	.855	301	<.001
Energy consumption per room night	.137	301	<.001	.861	301	<.001
Energy consumption per bed	.147	301	<.001	.852	301	<.001
Energy consumption per room	.151	301	<.001	.848	301	<.001

a. Lilliefors Significance Correction

Water Consumption

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total water consumption in '000 liter	.169	288	<.001	.787	288	<.001
Water consumption per guest night in liter	.116	288	<.001	.941	288	<.001
Water consumption per room night in liter	.134	288	<.001	.922	288	<.001
Water consumption per bed in '000 liter	.125	288	<.001	.908	288	<.001
Water consumption per room in '000 liter	.133	288	<.001	.893	288	<.001

a. Lilliefors Significance Correction

Figure 28: Tests of Normality
Source: Author's own data

The choice between these tests is often influenced by the sample size: the Shapiro-Wilk test is recommended for samples smaller than 50, while the Kolmogorov-Smirnov test is more suitable for samples equal to or larger than 50 (Mishra et al., 2019). Although both tests are evaluated, the Kolmogorov–Smirnov test is deemed more appropriate for this study, given the sample size of 301 hotels. Analysis of Figure 28 reveals that the

Kolmogorov-Smirnov p-values for all research variables are below 5%. Consequently, the population distribution of the eight independent variables analyzed is deemed non-normal. As previously discussed, several authors assume the normality of data above 30 data points (Bortz and Schuster, 2016). Even though the data set is above this limit, if appropriate non-parametrical tests conducted for further analysis are used to decrease bias and error possibilities.

6.2.2.2. Energy Consumption Correlation Analysis

Similar to other studies in the field, it is found that total energy (Bohdanowicz and Martinac, 2007; Priyadarsini et al., 2009) and water consumption (Alhudaithi et al., 2022; Deyà Tortella and Tirado, 2011) significantly correlate positively with guest nights sold. This result complements the often-argued necessity of building resource consumption ratios around occupant variables. Figure 29 displays scatter plots of the increasing resource consumption compared to total room nights.

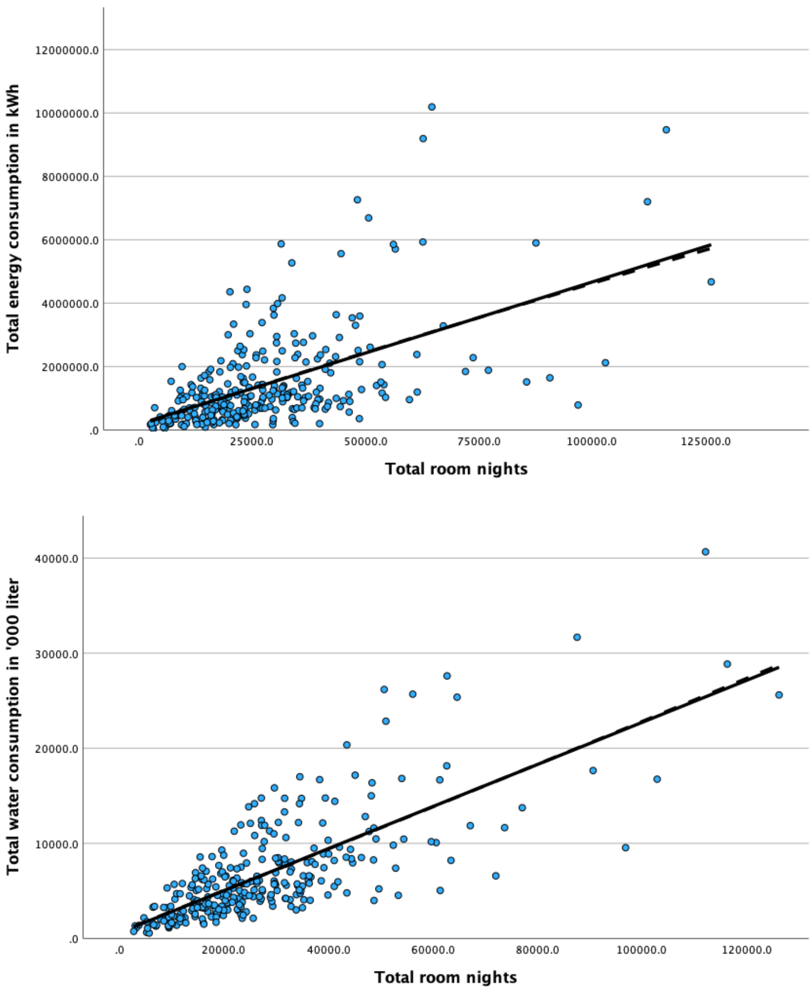

Figure 29: Regression Plots Total Guest Nights and Resource Consumption
Source: Author's own data

This study confirms that total energy consumption does not increase linearly with occupancy levels. As highlighted in previous research (Huang et al., 2015; Xuchao et al., 2010), a 100% increase in the number of occupants does not lead to a doubling of energy use. Therefore, for further correlation analysis, categorial and dichotomous independent variables are tested against the following dependent variables related to total consumption and occupant related intensity ratios:

- energy consumption in total (*ttl_energy*)
- energy consumption per room night (*energy_per_rn*)
- energy consumption per room (*energy_per_room*)

- water consumption in total (*ttl_water*)
- water consumption per room night (*water_per_rn*)
- water consumption per room (*water_per_room*)

The variables are selected based on existing academic studies, qualitative research findings, and quantitative research findings of the descriptive analyses. A non-parametric correlation test is necessary as the underlying data is non-normally distributed. The results and corresponding non-parametric test *Spearman's Rho* are tested and discussed in Table 55. Furthermore, if one variable is binary/dichotomous, dummy variables (e.g., wellness area existent "1", not existent "0") are created, and a *rank biserial test* is performed (see Table 56). As discussed previously, the confidence level is set at 95%.

	Total energy consumption in kWh	Energy consumption per room night	Energy consumption per room
Building Year	.140*	-.140*	-.138*
Number of floors	.251**	-.081	-.057
Number of restaurants	.314**	.286**	.238**
Number of rooms	.608**	.006	-.049
Number of beds	.614**	.023	-.027
Total guest nights	.558**	-.107	-.024
Total room nights	.551**	-.127*	-.044
Av. room occupancy	-.077	-.308**	-.009
Av. rate in Euro	.324**	.350**	.386**
Av. REVPAR in Euro	.299**	.177**	.334**
Total water consumption in '000 liter	.609**	.271**	.315**
Water consumption per guest night in liter	.270**	.432**	.399**
Water consumption per room night in liter	.286**	.444**	.417**
Water consumption per bed in '000 liter	.249**	.330**	.402**
Water consumption per room in '000 liter	.267**	.337**	.415**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 55: Energy Consumption and Secondary Continuous Determinants
Source: Author's own data

A negative correlation in occupancy levels related per room night (R = 0.308) but none in total energy consumption (R = -0.077) or per room (R = -0.009) are found. As the literature review indicates, a specific effect on occupancy level and energy consumption is evident, but no clear trend is measurable. This indicates that it is strongly related to the occupant rather than hotel size (AlFaris et al., 2016; Kim and Oldham, 2017; Lai, 2016; Lu et al., 2013; Priyadarsini et al., 2009; Nguyen and Rockwood, 2019). The building year has a considerably small significant positive correlation (R = 0.140) with total energy consumption but a negative one with per room night (R = -0.140) or per room perspective (R = -0.138). This result complements qualitative results, quantitative descriptive analyses, and other studies within this field (Nguyen and Rockwood, 2019). Therefore, no significant evidence that hotel age correlates with energy consumption was found, i.e., younger hotels are not generally more energy efficient than older hotels. Furthermore, strong evidence is found that when total energy consumption and energy consumption increase, water consumption figures and ratios surge alike. Therefore, a nexus of energy and water consumption, as concluded in the study of Becken and McLennan (2017), has been found as well in this study (further analysis in Chapter 6.2.2.4).

	Total energy consumption in kWh	Energy consumption per room night	Energy consumption per room
Star Rating	.284**	.263**	.280**
Chain Affiliation	.109	-.140*	-.186**
Wellness	.403**	.465**	.472**
Air conditioning	.114*	-.086	-.060
MICE	.271**	.341**	.295**
Type of F&B board	.200**	.341**	.291**
Location	.013	.278**	.247**
Building certification (DGNB, LEED)	-.068	-.073	-.051
Low energy building	-.108	-.094	-.087
Energy efficient building hull	-.130*	.015	.043
Energy efficient refurb of interior	-.224**	-.075	-.066
Roof insulation	-.131*	-.058	-.017
LED lamps > 90%	-.061	-.198**	-.129*
In room: minibar	-.255**	-.232**	-.262**
Green energy 100% of total consumption	-.136*	-.025	-.045
Laundry outsourced	-.085	-.077	-.070
Heating district heating	.088	-.151**	-.104
Electricity solar	-.112	-.038	-.069
Electricity photovoltaic	-.091	.114*	.091
HRMS	.119*	.029	.036

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 56: Energy Consumption and Secondary Dichotomous Determinants
Source: Author's own data

Total energy consumption and occupied rooms ratio strongly positively correlate with the number of rooms and beds. The same result can be concluded when analyzing type of F&B board, and number of restaurants. No clear trend is evident in chain affiliation and energy consumption with an R = 0.109 (total consumption) to R = -0.186 (consumption per room). Furthermore, as previously discussed, a wellness area significantly influences consumption and is strongly positively correlated. The same pattern is evident with regards to the existence of MICE areas. This is not surprising, as several studies found that resource consumption rises when size and service level increase (Tsai et al., 2014; Wang, 2012). Performance characteristics associated with a hotel's quality level, as indicated by star rating, along with the average room rate in euros and the resulting REVPAR exhibit a strong positive correlation with energy consumption levels. This complements several studies (Nguyen and Rockwood, 2019; Priyadarsini et al., 2009; Xuchao et al., 2010; Yao et al., 2015; Qi et al., 2017) and the qualitative interview findings stating that quality level strongly correlates with energy consumption.

Regarding hardware retrofitting, the presence of LED lamps and district heating in hotels shows a weak yet observable correlation with per room night resource consumption. Interestingly, the presence of a minibar found a correlation in all three variables, indicating that removing the minibar significantly affects energy consumption. Besides that, no major hardware retrofitting effort finds a significant correlation in ratios. Regarding total energy consumption a weak but significant correlation is found in energy-efficient building hull, refurb of interior and roof insulation. Therefore, a slight effect of these measures is statistically measurable. No correlation is found between the existence of sustainability certifications or low-energy buildings, underlining that these characteristics' impact is not statistically measurable. Furthermore, using renewable energy such as green energy, photovoltaic, or solar panels does not find any significant correlation with energy consumption variables. While descriptive statistics (see Chapter 6.2.1.7) suggest that laundry outsourcing has an observable effect, no significant correlation is identified in the correlation analysis.

6.2.2.3. Water Consumption Correlation Analysis

A similar inferential test process as in the previous section is conducted for water-related resource consumption correlations. The dependent variable measures total water consumption and ratios per room night and room. The results are illustrated in Table 57 and Table 58.

	Total water consumption in '000 liter	Water consumption per room night in liter	Water consumption per room in '000 liter
Building Year	.240**	-.140*	-.174**
Number of floors	.355**	-.058	-.034
Number of restaurants	.262**	.274**	.184**
Number of rooms	.714**	-.074	-.151*
Number of beds	.712**	-.053	-.125*
Total guest nights	.727**	-.122*	-.009
Total room nights	.735**	-.142*	-.027
Av. room occupancy	.073	-.161**	.290**
Av. rate in Euro	.275**	.353**	.391**
Av. REVPAR in Euro	.269**	.207**	.445**
Total energy consumption in kWh	.655**	.262**	.210**
Energy consumption per guest night	.229**	.416**	.266**
Energy consumption per room night	.244**	.438**	.290**
Energy consumption per bed	.278**	.350**	.331**
Energy consumption per room	.290**	.368**	.353**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 57: Water Consumption and Secondary Continuous Determinants
Source: Author's own data

Looking at the correlation coefficients obtained around water consumption (Table 57), an expected high positive correlation on total consumption is observed on the number of rooms (R = 0.714), room nights (R = 0.735), and beds (R = 0.712). The number of floors, which is closely linked to building size, also shows a strong correlation with total water consumption (R = 0.355). However, these independent variables find no or weak correlation when looking at intensity metrics per room night and room. This indicates that water usage is strongly dependent on the occupant rather than other factors. When analyzing the star rating, i.e., the quality level of a hotel, a correlation is found in all ratios. Further, a strong indication of the dependence of water consumption and quality level is the positive correlation found in av. rate (R = 0.391 water consumption per room) and consequently REVPAR (R = 0.445 water consumption per room). This result is similar to the findings of the qualitative interview section and other studies in this field (Barberán et al., 2013; Dinarès and Saurí, 2015; Rico-Amoros et al., 2009; Deng and Burnett, 2002; Gössling et al., 2012) agreeing that water consumption is directly and positively associated with the quality of a hotel. Dissimilar to other studies finding no correlation between occupancy levels and total water consumption (Charara et al., 2011; Deyà Tortella and Tirado, 2011), a negative correlation is found in WUPRN (R = -0.161) and a positive one in consumption per room (R = 0.290). Similar to the energy correlation section, there is no clear trend evident in chain affiliation and water consumption with an R = 0.118 (total consumption) to R = -0.268 (consumption per room).

Correlations

	Total water consumption in '000 liter	Water consumption per room night in liter	Water consumption per room in '000 liter
Star Rating	.224**	.296**	.225**
Chain Affiliation	.118*	-.276**	-.268**
Air conditioning	.287**	.129*	.124*
Wellness	.283**	.336**	.302**
MICE	.050	.138*	.017
Type of F&B board	.032	.200**	.116*
Location	-.209**	.101	.023
Building certification (DGNB, LEED)	-.017	-.081	-.126*
Digital monitoring tool for water consumption	.103	-.096	-.048
Information for guests on water efficiency measures	-.020	-.107	-.115
Use of flow limiters	.079	-.005	.044
Water efficient taps	.074	.052	.034
Water efficient toilet flush	-.056	.047	-.040
Water efficient shower heads	.012	.041	-.008
Water efficient urinals	.071	.075	.047
Use of water fittings with sensor technology in public areas	.093	.136*	.104
Toilet flush with stop function	.066	.008	.040
Automated irrigation systems	.141*	.172**	.191**
Laundry outsourced	-.044	-.031	-.010
Laundry in-house	-.115	.133*	.141*
Laundry outsourced <10km	.024	.040	.088
Laundry outsourced <20km	-.099	-.106	-.105
Laundry outsourced <30km	.017	.026	.006

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 58: Water Consumption and Secondary Dichotomous Determinants
Source: Author's own data

As discussed in the descriptive part, the existence of wellness facilities hugely impacts water consumption and is therefore found to be strongly positively correlated (R = 0.283 to 0.336). This is in line with the expected findings of the qualitative interview findings and previous studies (Bohdanowicz and Martinac, 2007; Deyà Tortella and Tirado, 2011; Warnken et al., 2005). Similar to the descriptive findings, the existence of MICE areas is non-correlated with water consumption, which is generally not surprising as the water consumption in these areas is usually limited. On the contrary, the existence of air-conditioning is correlated with water consumption. Although air-conditioning operations do not necessarily consume water resources, these systems are installed in higher-quality hotels explaining the correlation.

The type of F&B board does not possess a correlation in total consumption but finds a positive correlation in intensity metric perspective. This result may be due to the fact intensity metrics are more related to a particular entity (e.g., room or guest) and, therefore can better benchmark characteristics correlations. Interestingly, the location variable, so whether a hotel is located in urban or rural regions, shows significance in total water consumption metrics but not in the respective ratios. This result contrasts the energy consumption correlations where only the ratios are correlated with the independent variable. This finding warrants separate consideration, as it is generally acknowledged that countryside hotels tend to exhibit higher water consumption due to the presence of water-intensive facilities and outlets (e.g., spas, gardening, swimming pool). With respect to the implementation of water-saving measures in both hardware and operational environmental practices, the analysis reveals that almost no statistically significant correlations can be identified. Whereas this result contradicts previous studies such as Dinarès and Saurí (2015), a recent study of Antonova et al. (2023) found similar results. Automated irrigation systems find a correlation with all water consumption variables, finding that irrigation systems strongly affect water consumption. Dissimilar to the energy section, where no significant correlation between laundry location and resource consumption is identified, water consumption is indeed correlated with the location of laundry facilities. Although not considerably high, this indicates that outsourcing laundry generally reduces water consumption. Therefore, as postulated by Deng (2003) and Bohdanowicz and Martinac (2007) laundry location should be tracked and evaluated separately when doing water consumption benchmarking.

6.2.2.4. Energy-Water Consumption Nexus Correlation Analysis

Similar to the study of Becken and McLennan (2017) postulating that a strong nexus is evident, similar results are found in this study. Table 59 illustrates the high significance at the 0.01 level when energy and water-related metrics are correlated.

Correlations

	Total energy consumption in kWh	Energy consumption per guest night	Energy consumption per room night	Energy consumption per bed	Energy consumption per room	Total water consumption in '000 liter	Water consumption per guest night in liter	Water consumption per room night in liter	Water consumption per bed in '000 liter	Water consumption per room in '000 liter
Total energy consumption in kWh	1.000	.736**	.756**	.778**	.790**	.655**	.239**	.262**	.189**	.210**
Energy consumption per guest night	.736**	1.000	.976**	.947**	.914**	.229**	.453**	.416**	.308**	.266**
Energy consumption per room night	.756**	.976**	1.000	.926**	.942**	.244**	.416**	.438**	.276**	.290**
Energy consumption per bed	.778**	.947**	.926**	1.000	.975**	.278**	.380**	.350**	.362**	.331**
Energy consumption per room	.790**	.914**	.942**	.975**	1.000	.290**	.342**	.368**	.331**	.353**
Total water consumption in '000 liter	.655**	.229**	.244**	.278**	.290**	1.000	.486**	.515**	.507**	.536**
Water consumption per guest night in liter	.239**	.453**	.416**	.380**	.342**	.486**	1.000	.955**	.874**	.824**
Water consumption per room night in liter	.262**	.416**	.438**	.350**	.368**	.515**	.955**	1.000	.836**	.866**
Water consumption per bed in '000 liter	.189**	.308**	.276**	.362**	.331**	.507**	.874**	.836**	1.000	.959**
Water consumption per room in '000 liter	.210**	.266**	.290**	.331**	.353**	.536**	.824**	.866**	.959**	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

Table 59: Energy- and Water Consumption Nexus Correlation
Source: Author's own data

Notably, total energy consumption is strongly correlated with total water consumption ($R = 0.655$), suggesting that facilities with higher energy usage also tend to use more water, likely due to shared operational drivers such as guest volume and amenity offerings. Among intensity metrics, energy consumption per room night is positively correlated with water consumption per room night ($R = 0.438$), indicating a relationship between the efficiency of energy and water use relative to the occupant. Overall, the matrix highlights interconnected consumption patterns, reinforcing the value of integrated resource efficiency strategies.

6.2.2.5. Interaction Effects Model

Pairwise correlation analysis provides insights into the strength and direction of linear relationships between two variables, offering a preliminary understanding of potential associations within the dataset. To examine whether statistically significant differences exist between group means across categorical variables, analysis of variance (ANOVA) is applied. Specifically, the method is used to assess how hotel quality level (star rating: 1–5 stars), hotel size (<50 rooms, 50–100 rooms, 100–200 rooms, >200 rooms), and location (urban vs. rural) influence total energy consumption (Table 60).

Results show that the overall model is statistically significant ($F = 9.602$, $p < .001$). However, the model's R^2 value of 0.413 suggests that additional factors and variables beyond the one examined in this study play a significant role in influencing the outcome. Among the independent variables, the room number cluster has the strongest effect ($F = 14.814$, $p < .001$), indicating that hotels with more rooms tend to consume significantly more energy. The star rating variable also possess a significant impact ($F = 6.543$, $p = .002$), suggesting that higher-rated hotels have greater energy consumption. Additionally, the city vs. countryside variable is significant ($F = 6.352$, $p = .012$). These findings generally confirm the observations within the correlation analysis chapter (see Chapter 6.2.2.2).

Tests of Between-Subjects Effects

Dependent Variable: Total energy consumption in kWh

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2.826E+14[a]	20	1.413E+13	9.602	<.001	.413
Intercept	1.735E+14	1	1.735E+14	117.917	<.001	.302
City_Countryside	9.347E+12	1	9.347E+12	6.352	.012	.023
Star_Rating	1.926E+13	2	9.628E+12	6.543	.002	.046
Room_Number_Cluster	6.540E+13	3	2.180E+13	14.814	<.001	.140
City_Countryside * Star_Rating	7.973E+12	2	3.987E+12	2.709	.068	.019
City_Countryside * Room_Number_Cluster	2.052E+12	3	6.838E+11	.465	.707	.005
Star_Rating * Room_Number_Cluster	1.973E+13	5	3.946E+12	2.681	.022	.047
City_Countryside * Star_Rating * Room_Number_Cluster	3.965E+12	4	9.913E+11	.674	.611	.010
Error	4.017E+14	273	1.472E+12			
Total	1.320E+15	294				
Corrected Total	6.843E+14	293				

a. R Squared = .413 (Adjusted R Squared = .370)

Table 60: Interaction Effects Model
Source: Author's own data

When analyzing the interactions, the star rating × room number cluster is significant ($F = 2.681$, $p = .022$), indicating that the combined impact of star rating and hotel size influences energy consumption. Therefore, it can be concluded that larger hotels with higher star ratings consume more energy than expected from each factor alone. However, the interaction between star rating × location cluster is not statistically significant ($p = .068$), suggesting that star rating impacts energy consumption similarly in urban and rural settings. Additionally, the three-way interaction (Star rating × room number cluster × city vs. countryside) is not significant ($p = .611$), indicating that these variables operate largely independently rather than in combination. Therefore, a more complex model inheriting additional independent variables is perceived as unfeasible at this stage.

6.2.2.6. Regression Model Total Energy Consumption

As previously noted, the goal is to develop a comprehensive model specifying factors determining energy consumption within the region under research. Regarding variables used for the model, total resource consumption is identified as the dependent variable. As this variable is categorized as continuous, linear regression modeling is used (see Chapter 4.3.3.2 for assumptions in linear regression modeling). Beginning with a base model incorporating findings from previous analysis , independent variables are incrementally introduced to identify strong predictors of energy consumption and to construct a robust annual consumption model. Multiple preliminary models are developed, each based on a broad spectrum of continuous and dichotomous variables. This approach enables the systematic evaluation of key operational and physical hotel characteristics that may significantly influence total energy consumption. The estimated coefficients are tangled around the same characteristics, demonstrating the robustness of the estimations. Likewise to other studies in the field (Bohdanowicz and Martinac, 2007; Deng and Burnett, 2000; Deyà Tortella and Tirado, 2011) a constant term is integrated in the model. The models' significance is <5%, indicating a regression relation between the independent and dependent variables. To assess multicollinearity between variables, the variance inflation factor (VIF) is analyzed and, according to the literature, set to be below 2 (Kim, 2019; Oke et al., 2019).

Following the design of the regression approach, the final model estimating total energy consumption is specified as follows. Similar to the regression model of Wang (2012), the number of rooms has the highest influence on total energy consumption. Furthermore, the KPI REVPAR (av. rate multiplied with av. occupancy) is integrated to depict an occupancy-related as well as quality level-related variable. In addition, the number of

MICE rooms and restaurants is found to be significant. As indicated by the study of Becken and McLennan (2017) a strong relationship between energy and water consumption is found and integrated into the regression model presented. Additionally, the presence of wellness areas is found to be a significant factor in the model. The following regression equation is derived from the model presented in Table 61.

$$\begin{aligned} &Total\ energy\ consumption \\ &\quad = 7{,}435.39 \times av.REVPAR\ in\ Euro + 10{,}229.24 \times number\ of\ rooms \\ &\quad + 47{,}229.79 \times number\ of\ MICE\ rooms \\ &\quad + 39{,}414.18 \times number\ of\ floors \\ &\quad + 3{,}921.58 \times water\ consumption\ per\ room\ in\ '000 liter \\ &\quad + 522{,}783.32 \times existence\ of\ wellness\ area \\ &\quad + 105{,}902.76\ (location\ countryside) - 1{,}530{,}135.72 \end{aligned}$$

Where $R^2 = 0.620$ and a VIF below 2, which can be generally rated as satisfactory to predict annual energy consumption in the hotel industry.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.787[a]	.620	.610	975234.5776

a. Predictors: (Constant), Location, Av. REVPAR in Euro, Number of MICE rooms, Number of floors, Water consumption per room in '000 liter, Wellness, Number of rooms

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.202E+14	7	6.003E+13	63.119	<.001[b]
	Residual	2.577E+14	271	9.511E+11		
	Total	6.780E+14	278			

a. Dependent Variable: Total energy consumption in kWh

b. Predictors: (Constant), Location, Av. REVPAR in Euro, Number of MICE rooms, Number of floors, Water consumption per room in '000 liter, Wellness, Number of rooms

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-1530135.72	210690.412		-7.262	<.001		
	Number of rooms	10229.245	901.517	.510	11.347	<.001	.693	1.442
	Number of floors	39414.181	15862.180	.100	2.485	.014	.860	1.162
	Number of MICE rooms	47229.792	9502.418	.219	4.970	<.001	.722	1.384
	Wellness	522783.327	139093.356	.163	3.759	<.001	.745	1.342
	Av. REVPAR in Euro	7435.390	1263.937	.252	5.883	<.001	.765	1.308
	Water consumption per room in '000 liter	3921.580	972.291	.174	4.033	<.001	.756	1.323
	Location	105902.760	46572.724	.102	2.274	.024	.702	1.424

a. Dependent Variable: Total energy consumption in kWh

Table 61: Regression Model Total Energy Consumption
Source: Author's own data

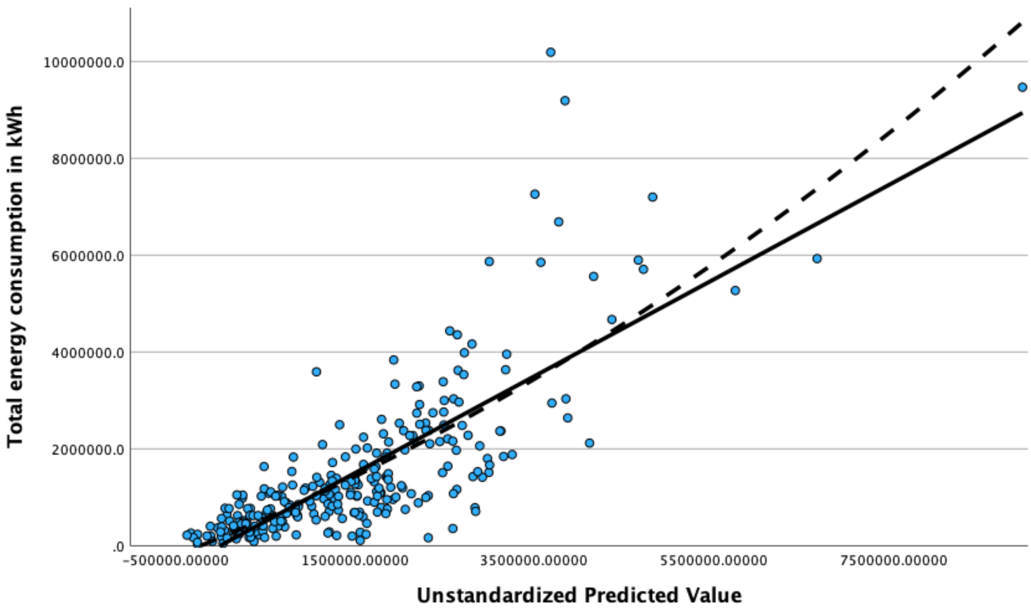

Figure 30: Scatter Plot Predicted vs. Actual Energy Consumption
Source: Author's own data

While analyzing outliers below and above the trend line of Figure 30, the following findings are observed. First, extensive scaled properties (> 500 rooms) consume decreasingly less total energy than the predicted regression model. Second, the same pattern is concluded with low-quality hotels. Second, 5-star properties in countryside regions with resource-extensive outlets may consume five times more than same-sized city hotels, leading to disproportional values. Nevertheless, it is discovered that those kind of properties generally invest more money in sustainability matters. Third, unique-use properties (homes for aviation staff and low-quality MICE hotels) may distort values and generate outliers. The high negative constant term possesses a high significance level (<0.001), confirming that a misspecification could lead to a bias in the regression estimations. Furthermore, the high constant value indicates a very heterogeneous data set, representing the huge variety of the German and Austrian hotel industry.

When reviewing the variable values of all hotels sequentially case by case[31], factors that can improve the accuracy of the proposed correlations are identified. In a refinement process, different hotel clusters were evaluated based on their R^2 results, aligning with their descriptive statistics. The model developed in Table 62 incorporates location and star-rating variables to enhance predictive accuracy. Among the analyzed clusters, 4-star city hotels emerged as the most homogeneous group and the largest subset in the dataset, comprising 77 hotels. Notably, in addition to the variables included in the total energy

[31] The characteristics of the sample hotels are input into the presented linear regression equation and subsequently compared to the reported actual values. The deviations between the predicted and observed values are then analyzed, with corresponding explanations provided for the discrepancies.

consumption regression model, the number of restaurants and the number of MICE rooms are found to be significant for this category. The 4-star city hotel cluster achieves a high R^2 value, demonstrating strong explanatory power in the linear regression model.

$$\begin{aligned} &4\ star\ city\ hotel\ total\ energy\ consumption \\ &\quad = 6{,}791.569 \times av.REVPAR\ in\ Euro + 8{,}706.26 \times number\ of\ rooms \\ &\quad + 60{,}180.88 \times number\ of\ MICE\ rooms \\ &\quad + 292{,}421.01 \times number\ of\ restaurants \\ &\quad + 6{,}458.65 \times water\ consumption\ per\ room \\ &\quad + 451{,}069.02 \times existence\ of\ wellness\ area - 1{,}656{,}228.08 \end{aligned}$$

Where $R^2 = 0.736$ and a VIF below 2, which can be generally rated as highly satisfactory to predict annual energy consumption for a 4-star city hotel. The strong model fit is as well observable in the scatter plot illustrated in Figure 31.

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.858[b]	.736	.706	704323.9050

a. Star Rating = Upscale (4 star), Location = City

b. Predictors: (Constant), Number of restaurants, Av. REVPAR in Euro, Wellness, Number of floors, Number of rooms, Number of MICE rooms, Water consumption per room in '000 liter

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.583E+13	7	1.226E+13	24.717	<.001[c]
	Residual	3.076E+13	62	4.961E+11		
	Total	1.166E+14	69			

a. Star Rating = Upscale (4 star), Location = City

b. Dependent Variable: Total energy consumption in kWh

c. Predictors: (Constant), Number of restaurants, Av. REVPAR in Euro, Wellness, Number of floors, Number of rooms, Number of MICE rooms, Water consumption per room in '000 liter

Coefficients[a,b]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-1656228.05	281183.068		-5.890	<.001		
	Number of rooms	8706.261	1297.602	.507	6.710	<.001	.745	1.343
	Number of floors	33118.958	12866.413	.173	2.574	.012	.942	1.061
	Number of MICE rooms	60180.884	28997.391	.161	2.075	.042	.707	1.415
	Wellness	451069.022	207260.599	.147	2.176	.033	.936	1.069
	Av. REVPAR in Euro	6791.569	2644.211	.205	2.568	.013	.671	1.491
	Water consumption per room in '000 liter	6458.655	2067.110	.251	3.124	.003	.657	1.522
	Number of restaurants	292421.012	112985.991	.174	2.588	.012	.939	1.065

a. Star Rating = Upscale (4 star), Location = City

b. Dependent Variable: Total energy consumption in kWh

Table 62: Regression Model Total Energy Consumption 4-star City Hotel
Source: Author's own data

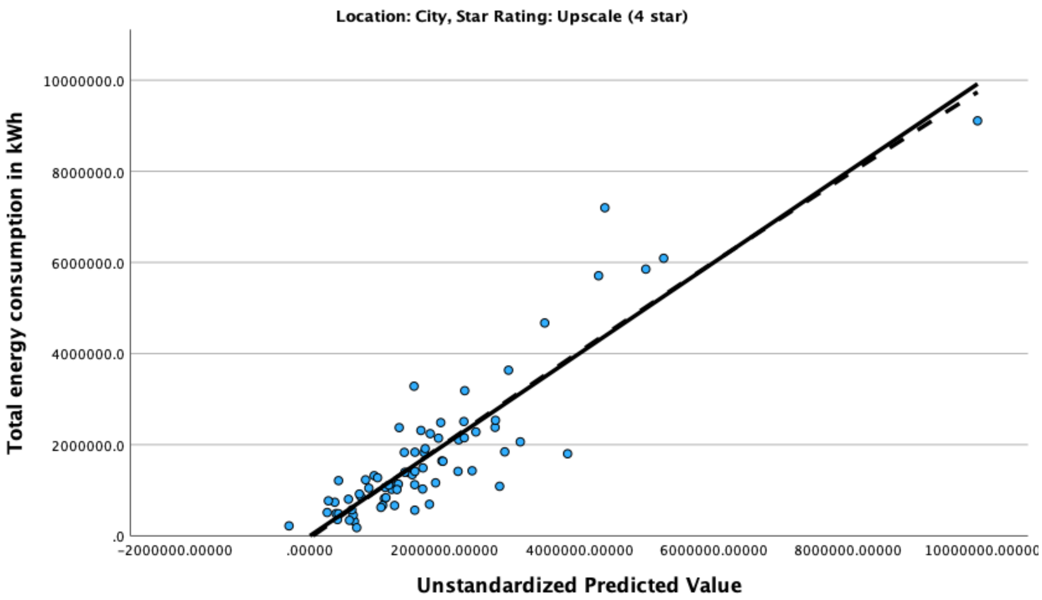

Figure 31: Scatter Plot Predicted vs. Actual Energy Consumption 4-star City Hotel
Source: Author's own data

6.2.2.7. Regression Model Total Water Consumption

Similar to the energy consumption regression model, determinants for water consumption are tested through multiple linear regression models. This process follows the same approach as previously described for energy consumption, ensuring consistency in the evaluation of relevant variables. Refining the regression model by focusing exclusively on a specific cluster (e.g., four-star hotels) did not result in any significant enhancement of the model's predictive capability. The final model for water consumption is as follows.

$$\begin{aligned} &Total\ water\ consumption \\ &= 50.984 \times number\ of\ rooms + 976.323 \times number\ of\ restaurants \\ &+ 74.556 \times av.room\ occupancy + 30.156 \times av.rate\ in\ Euro \\ &+ 904.382 \times existence\ of\ wellness\ area \\ &- 1231.574 \times water\ efficient\ toilet\ flush - 7{,}954.493 \end{aligned}$$

With $R^2 = 0.661$ and a VIF below 2, the model can be generally rated robust to predict water consumption in the German and Austrian hotel industry (see Table 63).

As postulated in different studies, the main contributor to water consumption is the size of the hotel, i.e., the number of rooms (Bohdanowicz and Martinac, 2007; Deyà Tortella and Tirado, 2011). Furthermore, the model focuses on incorporating water-intensive outlets such as wellness areas and restaurants. A high significance is found in spa and wellness outlets, which is in contrast to previous literature (Bohdanowicz and Martinac, 2007; Deyà Tortella and Tirado, 2011). Similar to the energy consumption model, performance-related KPIs are found to be significant. While other studies found significance in the type of F&B board (Deyà Tortella and Tirado, 2011), the characteristic is non-significant in this respective data set. Although a correlation between total water consumption and chain affiliation is observed, no statistical significance is found in the regression model.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.813[a]	.661	.654	3273.9836

a. Predictors: (Constant), Water efficient toilet flush, Av. rate in Euro, Number of rooms, Av. room occupancy, Number of restaurants, Wellness

b. Dependent Variable: Total water consumption in '000 liter

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5884325164	6	980720861	91.494	<.001[b]
	Residual	3012030143	281	10718968.5		
	Total	8896355308	287			

a. Dependent Variable: Total water consumption in '000 liter

b. Predictors: (Constant), Water efficient toilet flush, Av. rate in Euro, Number of rooms, Av. room occupancy, Number of restaurants, Wellness

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-7954.493	1258.276		-6.322	<.001		
	Number of rooms	50.984	2.603	.693	19.587	<.001	.963	1.038
	Number of restaurants	976.323	317.193	.116	3.078	.002	.849	1.178
	Av. room occupancy	74.556	15.253	.178	4.888	<.001	.913	1.095
	Av. rate in Euro	30.156	4.736	.255	6.367	<.001	.751	1.331
	Wellness	904.382	455.225	.077	1.987	.048	.792	1.262
	Water efficient toilet flush	-1231.574	550.583	-.079	-2.237	.026	.967	1.035

a. Dependent Variable: Total water consumption in '000 liter

Table 63: Regression Model Total Water Consumption
Source: Author's own data

While operational environmental efforts were not included in the model, testing against hardware environmental retrofitting revealed that water-efficient toilet flush systems are significant and thus incorporated into the model. No other relevant water-saving initiatives are found to be significant. The laundry variables were also tested, but a significance level slightly above 5% (approximately 10%) prevented their inclusion in the model. In contrast to the energy consumption regression model, no significant relationship with energy-related variables is identified within the water consumption regression model. Similar to the energy consumption regression model, the data points exhibiting the greatest deviation, particularly at higher predicted values, are further examined based on the scatter plot presented in Figure 32.

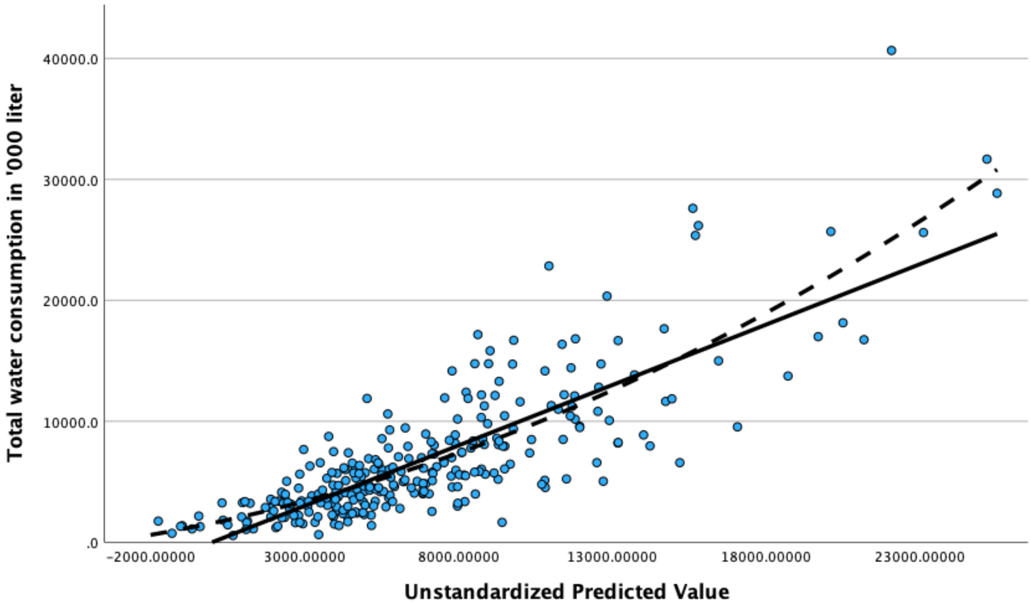

Figure 32: Scatter Plot Predicted vs. Actual Water Consumption
Source: Author's own data

At the upper end of the distribution, it is observed that large-scale ultra-luxury hotels located in rural areas consume significantly more water than the average, following an exponential trend. In contrast, large-scale hotels of lower quality tend to exhibit below-average water consumption. These deviations from the general pattern suggest that such atypical hotel types require separate modeling approaches and additional consideration in both predictive analysis and policy formulation.

6.3. Discussion and Conclusion Quantitative Research Stage

To develop a benchmarking model, stepwise linear regression is conducted following a correlation analysis to predict energy and water consumption within the German and Austrian hotel industry. This section discusses the hypotheses formulated in the methodology chapter (Chapter 4) in light of the empirical results.

Hypothesis 12:

H_0: There is a positive correlation between energy and water audit results and the quality level of a hotel.

This hypothesis is supported. Whereas the interview experts already expected a high correlation, it is found that energy consumption per room night of 5-star hotels (EUPRN 82.2 kWh) is 95% higher than in 3-star hotels (EUPRN 42.2 kWh). A similar pattern is evident with regard to water consumption (WUPRN 5-star 437.9 liters, 3-star 234.6 liters, +84.6%). Furthermore, the Spearman Rho correlation coefficient indicates a high correlation (Energy R = 0.263, Water R = 0.296). These findings empirically validate the hypothesis, confirming that hotel classification is a significant predictor of both energy and water consumption intensity.

Hypothesis 13:

H_0: There is a positive correlation between environmental Resource consumption and the type of F&B service of a hotel.

This hypothesis is supported. Generally, it is found that the higher the service level, the higher the resource consumption. This is especially the case with F&B service level, where energy and water consumption per room night significantly increases with a full-service hotel (e.g., EUPRN 78.2 kWh full restaurant vs. EUPRN 48.4 kWh breakfast only, +61,5%). Furthermore, correlations between the number of restaurants and energy and water consumption per room night are proven to be significant. These results confirm the hypothesis, demonstrating that higher service levels, particularly in F&B offerings, are strongly associated with increased energy and water consumption per room night.

Hypothesis 14:

H_0: Higher average room prices positively correlate with total energy and water consumption and hotel intensity metrics.

This hypothesis is supported by the findings. Given that room prices typically reflect the quality level of a hotel, averaging 81.6 Euro for 3-star, 123.4 Euro for 4-star, and 248.6 Euro for 5-star establishments, a corresponding pattern of resource consumption emerges, consistent with the observations reported in Hypothesis 12.

Hypothesis 15:

H_0: There is no significant difference in energy and water efficiency between older and newer hotel buildings.

This hypothesis is partly supported. Within this study hotels are clustered built before 1950 (Cluster 1), built between 1950 and 2000 (Cluster 2), and built after 2000 (Cluster 3). With regards to energy consumption per guest night, a slightly higher consumption towards older hotels is witnessed (46.2 kWh before 1950, 35 kWh after 2000, +32%). The same pattern is evident in water consumption. However, with the performed correlation analysis only a weak significance between energy and water consumption and building year has been found. Therefore, it has to be acknowledged that the building age is not similar to the condition of the building or the last major renovation.

Hypothesis 16:

H_0: Hotels that adopt green operational practices or hardware retrofitting experience a measurable decrease in resource consumption compared to those that do not.

This hypothesis is rejected. A total of approximately 50 hardware retrofitting and operational environmental practices were examined. Although 5-star properties tend to implement a greater number of green practices, no measurable effect on overall resource efficiency could be identified. A modest impact is observed in water consumption, particularly in relation to water-saving measures such as low-flow shower heads and toilet flush systems. However, this effect remains too limited to support definitive conclusions.

Hypothesis 17:

H_0: Resource consumption patterns are similar between urban and rural hotels.

This hypothesis is rejected. This study finds that city hotels are generally more resource-efficient than countryside hotels. Energy (EUPGN 27.4 kWh in city hotels, 44.1 kWh in countryside hotels, +60.9%) and water consumption (WUPGN 168.3 liters in city hotel, 236.1, liters in countryside hotels, +40.2%) differs considerably.

Hypothesis 18:

H_0: Hotels that outsource their laundry services exhibit lower resource consumption compared to hotels that manage laundry in-house.

This hypothesis is supported. This study reveals that hotels outsourcing their laundry possess a statistically measurable decrease in energy (EUPGN 48.8 kWh non-outsourced vs. 34.9 kWh outsourced, +39,8%) and water consumption (WUPGN 285 liters non-outsourced vs. 170.8 liters outsourced, +66.8%). These findings demonstrate that outsourcing laundry services is associated with a significant reduction in both energy and water consumption in hotel operations.

Hypothesis 19:

H_0: Total resource consumption and associated intensity metrics are the same between hotels with dedicated MICE areas and hotels without such facilities.

This hypothesis is partly supported. While no statistically significant differences are observed in water consumption between hotels with and without MICE areas (WUPRN 313.4 liters vs. 284.6 liters, +10.1%), energy consumption is notably affected by the presence of such facilities. Hotels with MICE areas exhibit substantially higher energy use per room night (EUPRN 59.7 kWh) compared to those without (38 kWh), representing an increase of 57.1%. These findings suggest that although MICE areas do not considerably influence water usage, they contribute significantly to elevated energy demand, likely due to increased lighting, heating, cooling, and equipment usage associated with event and conference operations.

Hypothesis 20:

H_0: Total resource consumption and associated intensity metrics are the same between hotels with dedicated wellness areas and hotels without such facilities.

This hypothesis is rejected. Wellness areas strongly affect energy (EUPGN 53.5 kWh wellness area vs. 26 kWh no wellness, +105%) and water consumption (WUPGN 286.8 liters wellness area vs. 153.7 liters no wellness, +86.6%). This effect is further substantiated by the correlation coefficients, indicating a moderate positive relationship between the presence of wellness areas and resource consumption: R = 0.465 for energy (Wellness / EUPRN) and R = 0.336 for water (Wellness / WUPRN).

Hypothesis 21:

H_0: There is no significant difference in resource consumption between chain-affiliated and independent hotels.

This hypothesis is partly supported. The analysis reveals moderately higher levels of both energy and water consumption in unaffiliated hotels compared to their affiliated counterparts. Specifically, unaffiliated hotels consume 41.5 kWh of energy per guest night, compared to 33.5 kWh in affiliated hotels, reflecting a 23.8% increase. Similarly, water consumption per guest night is higher in unaffiliated hotels at 238.8 liters, compared to 184.5 liters in affiliated hotels, representing a 29.4% increase. These differences may be attributed to variations in operational efficiency, standardization of practices, and access to centralized sustainability initiatives commonly present in affiliated hotel groups.

Hypothesis 22:

H_0: Hotels equipped with air-conditioning systems consume more electricity than hotels without air-conditioning systems due to the additional electricity requirements for cooling and climate control.

This hypothesis is partly supported. A slight effect is observed in energy use per room night (EUPRN), with values increasing from 17.4 kWh in hotels without air-conditioning to 21.5 kWh in those with air-conditioning (+23.5%). However, this difference may be confounded by additional variables, particularly the quality classification of the hotels. Air-conditioned establishments are predominantly found within the four- and five-star categories, suggesting that higher energy consumption may also be influenced by the broader service offerings.

Hypothesis 23:

H_0: Regression models for energy consumption are reliable in predicting total resource consumption in the German and Austrian hotel industry.

This hypothesis is partly supported. Predicting total energy consumption on the whole data set proved satisfactory. It is found that number of rooms, number of MICE rooms, number of floors, location existence of wellness area and performance metrics such as REVPAR are main contributors for energy and water consumption. A high REVPAR is also positively associated with the quality level of a hotel. Hotels in higher star categories generally achieve greater REVPAR, reflecting enhanced service offerings, amenities, and overall operational standards typical of upscale accommodations. The further refinement process of the regression model reveals that, hotels with a more consistent standard and location, like 4-star city accommodations, exhibit greater predictability and achieve a higher R^2 value. The development of a regression model using intensity metrics as the dependent variable yields an R^2 value below 0.6, indicating a low level of explanatory power and poor model fit. As a result, this approach is not considered suitable for the current analysis but may warrant further investigation in future research, potentially with an expanded dataset or additional explanatory variables.

Hypothesis 24:

H_0: Regression models for water consumption are reliable in predicting total resource consumption in the German and Austrian hotel industry.

This hypothesis is supported. Similar to energy regression modeling, water consumption regression models are based on the number of rooms, number of restaurants, presence of a wellness area, and the average room rate as a performance metric reflecting the quality level of the hotel. Interestingly, a hardware retrofit, the installation of water-efficient toilet flush systems, proves significant for the overall regression. The overall model shows a good fit, with an R^2 value above 0.6, indicating a satisfactory level of explanatory power.

Hypothesis 25:

H_0: There is a statistically significant difference in total energy consumption based on at least one of the independent variables (star rating, hotel size, or location) or their interactions.

The hypothesis is supported, as there is a statistically significant difference in total energy consumption based on at least one of the independent variables. Although the overall model is significant, a considerably low R^2 value is found ($R^2 = 0.413$). The Star Rating × Room Number Cluster interaction is significant ($F = 2.681$), meaning that larger hotels with higher star ratings consume more energy than expected from each factor alone. However, the three-way interaction (Star Rating × Room Number Cluster × Location) is not significant ($F = 0.674$, $p = 0.611$), suggesting that these factors do not combine in a way that meaningfully influences energy use. While the model confirms that hotel size, star rating, and location significantly impact energy consumption, the moderate effect size suggests that additional factors may be needed to explain variations in hotel energy use better. These factors could include:

- Operational Practices: Variations in energy efficiency measures, including energy-saving technologies (displayed in Chapter 6.2.1.5) or staff training on energy conservation (as highlighted in the qualitative research findings)
- Guest Behaviors: The number of guests, their behavior (e.g., use of air-conditioning, lighting, etc.), and occupancy rates
- Building Infrastructure: Older hotels may have outdated insulation, less efficient heating and cooling systems, and other infrastructure-related inefficiencies.

Hypothesis 26:

H_0: There exists an energy- and water-consumption nexus in resource consumption in hotel real estate.

The hypothesis is supported. The analysis reveals statistically significant correlations between energy and water consumption indicators in hotel operations, indicating a clear nexus in resource consumption. Total energy consumption is positively correlated with total water consumption ($R = 0.655$), and intensity metrics such as energy and water consumption per room night also show a meaningful relationship ($R = 0.438$), both significant at the 0.01 level. These results suggest that patterns of energy and water use are interrelated, likely influenced by shared operational factors such as guest volume and service provisions. Therefore, the presence of an energy–water consumption nexus across the analyzed data set hotel industry is empirically validated.

7. Discussion and Conclusion

This final section is dedicated to a comprehensive discussion of the findings, offering a detailed analysis of the results. It also includes a recap of the initial aims and objectives outlined in Chapter 1.2. This synthesis aims to contextualize the findings within the broader scope of the research and highlight their implications.

The call for a more environmentally sustainable approach to the development, operation, and performance of hotels resonates strongly among stakeholders within the tourism and hospitality industries. While the hotel sector possesses numerous commendable eco-initiatives, they often remain isolated examples rather than the norm. However, the promise of substantial cost savings, legislative measures, and the growing demand from consumers are increasingly fostering hoteliers toward greater environmental responsibility. Furthermore, the establishment of reliable metrics and comparison schemes is essential for sustainability assessments and reporting. Developing tailored models for different characteristics of hotels, rather than pursuing a one-size-fits-all approach, holds promise for more accurate insights into resource consumption and performance optimization. Despite a decisive call that environmental awareness among European hoteliers needs to be increased (Bohdanowicz, 2005; Campos et al., 2024), study findings within the scientific literature and qualitative phase indicate that there is still room for improvement in the current status.

The research results of this doctoral dissertation present a significant contribution to shed light on the above-outlined challenges. The research process is designed to be reproducible and derived from previous studies in this field. The research begins with a SLR of approximately 1,600 articles. These findings, combined with an analysis of existing initiatives and legislative standards, form the foundation for subsequent research steps. The empirical methodology employed in this research project adheres to an explanatory sequential mixed methods design. It is characterized by an initial qualitative phase involving 16 semi-structured expert interviews, followed by quantitative research and successive application of the findings to a data set consisting of 301 hotels. A total of 26 hypotheses are formulated to address the initial research objectives, with their outcomes subsequently summarized and discussed in the following paragraphs. The SLR presented in this study serves as a comprehensive and methodologically rigorous synthesis of existing research on environmental resource consumption in the hotel industry. Guided by reproducible research criteria, the review involves an extensive keyword-based search across major databases, screening over 1,600 studies and narrowing the scope to 117 articles for detailed analysis. The review reveals a maturing research field with growing relevance, particularly dominated by energy and water consumption studies, while waste and GHG monitoring remain comparatively underexplored. A key contribution of this review lies in the critical synthesis of intensity metrics used to benchmark consumption, highlighting the need for multi-dimensional indicators that incorporate both resource input and user-related reference units. Among these, the most relevant intensity metrics derived from the frequency of occurrence and are outlined in Table 12. It underscores inconsistencies in data collection and methodological approaches, revealing significant gaps in geographic coverage and underlines the importance of standardized benchmarking practices. Existing sustainability frameworks and industry initiatives provide a robust foundation for developing resource intensity metrics in the hotel sector. While the ESRS emphasize revenue-based indicators, they recognize the need for sector-specific metrics. Tools such as EMAS, GSTC, HCMI, HWMI, and the Sustainable Hospitality Alliance's waste methodology offer standardized indicators, with some already widely adopted. However, their full potential relies on broader implementation across the industry. Despite these available resources, ESG reporting of the largest hotel companies remains fragmented, and a clear, unified approach to EGWW intensity metrics has yet to be established, highlighting a critical need for consistent, sector-specific standards.

This gap becomes even more apparent when considering insights from the qualitative phase of this research, which involved interviews with 16 industry experts. First and foremost, the German and Austrian hotel industry has improbable knowledge about ESG fundamentals, reporting, and benchmarking. Furthermore, existing operator and lease contracts do not have clauses implementing reporting of ESG measures to real estate owners. This challenge significantly hinders compliance with legislative regulations. Similar to the SLR, energy and water measurements are done more frequently than waste consumption measurements. Even with large institutional investors, the calculation of the GHG footprint is only done rarely as well as boundaries are not clearly set. Several legislative frameworks are expected to drive an increase in the measurement of GHG emissions in the future. Firstly, the EU Taxonomy and the CSRD aim enhancing transparency by requiring the disclosure of GHG emissions. Secondly, the introduction of CO_2 taxation and related financial compensation mechanisms is placing growing pressure on both owners and operators. Thirdly, the EU Supply Chain Act incentivizes companies to monitor and manage their environmental footprint more comprehensively. In this study, a definition of GHG emissions boundaries for the hotel industry is elaborated (see Figure 19)f.

Interviewees agree that when measuring resource consumption, the establishment of intensity indicators increases comparability. There, a per-floor measurement and a user-centric approach are recommended. When data is available, zoning of hotel areas is preferred. Furthermore, to consider ESRS obligations, reporting in resource consumption per million net revenue is recommended. However, the experts emphasize the clear lack of data availability and the knowledge necessary to analyze the existing data. This study finds that even when measurements are taken, they are often not yet processed or transformed into management actions. When benchmarking is performed, interviewees agree that operational and hardware characteristics must be distinguished to generate a valid peer set. To conclude, it is highlighted that efforts to enhance environmental management and resource efficiency in the hospitality sector necessitate commitment, collaboration, achievable goals, effective communication, and continuous improvement. Legislative measures, economic incentives, and management commitment are pivotal in driving change across the industry. There is an increasing recognition of the need to translate this awareness into measurable indicators, alongside the development of a robust and valid benchmarking framework. Nevertheless, a foundational approach for establishing ESG-compliant EGWW intensity metrics is outlined (see Chapter 5.3.1), demonstrating general alignment with the requirements and frameworks of EMAS, ESRS, GSTC, and HWMI. Furthermore, the study elaborates on the key differentiating determinants of hotel properties by categorizing them into operational, physical, and external factors, thereby laying the groundwork for a more nuanced and context-sensitive application of benchmarking practices.

Building on the established set of intensity metrics and the conceptual framework of differentiating characteristics, the quantitative phase of the study applies the developed indicators to empirically assess resource consumption patterns. The analysis begins with a rigorous data-cleaning process and draws on a sample of 301 hotel establishments in Germany and Austria. This provides a unique empirical foundation for exploring energy and water consumption patterns. The dataset incorporates both resource use and operational characteristics, comprising a total of 148 numeric and dichotomous variables. According to the findings of the SLR, this study marks the third-largest resource consumption benchmarking study globally and the first large-scaled study in Central Europe. With regard to data availability, auditable numbers for waste and GHG figures were not provided. Similar to the results of the qualitative interviews, such figures are not evident and are designated for further research. Quantitative results of resource consumption indicate that the data set is highly heterogonous. Nevertheless, the energy consumption per occupied room is, on average, 54.2 kWh, considerably lower than in other parts of the world. With regards to water consumption, an average consumption of 306.2 liters per room night, a similar pattern is discovered. The study delves into the various building attributes and operational practices influencing differences in hotel energy and water performance. Considerable high deviations in resource consumption are found in the quality level (star rating), location (urban/rural), building age, or existence of wellness area, which generally complements previous studies in this research field. Interestingly, although energy consumption per occupant remains constant regardless of hotel size, water consumption significantly decreases in larger hotels above 200 rooms.

The energy mix encountered is different from audits in other parts of the world, as heating in the German and Austrian hotel industry is predominantly done with radiators rather than with air-conditioning facilities. Furthermore, a huge potential in using Green electricity as well as retrofitting hardware in energy and water matters has been discovered. For example, while analyzing building age, a considerably small increase in electricity consumption per room night between hotels built before 1950 and after 2000 is found. However, heating consumption in older hotels is considerably higher, indicating that building hardware such as wall and/or window insulation is better in newer hotels. This study focused on the hotel's construction date rather than major renovations, making it difficult to assess the impact of renovations. With regards to the HVAC system, it is revealed that air-conditioning in a hotel increases electricity consumption by 23.6% on average. Contrary to previous scientific studies, the effect of chain affiliation on resource consumption has been analyzed. The findings reveal that chain-affiliated hotels are generally more resource-efficient. In addition, this study finds that while hardware retrofitting and operational sustainability activities are incorporated into daily business routines, their statistical effects on resource consumption are not yet measurable. However, there is a trend towards higher-level hotels investing more in sustainability measures (e.g., share of retrofitting hardware and operational practices). Furthermore, strong evidence is found that when energy consumption increases, water consumption figures and ratios surge alike. Therefore, a nexus of energy and water consumption, as concluded in the study of Becken and McLennan (2017), is found as well in this study. Dissimilar to energy consumption patterns, a significant negative correlation in water consumption is found when hotels possess outsourced laundry. Furthermore, implementing operational sustainable activities and hardware retrofitting is found improvable. In particular, easily retrofittable equipment is find increasingly employed, such as LED lighting, light sensors, energy-efficient televisions, and flow limiters in bathrooms and toilets. Sustainable equipment is more frequently found in higher-end hotels. However, systems for rainwater collection, greywater treatment, and reuse are scarcely available; such systems are considerably more prevalent in other parts of the world. Furthermore, a considerably low green electricity share of about 50% of data set hotels is found, leaving room for improvement. Green electricity is pivotal to considerably decrease one's GHG footprint without changing existing hardware. A final presentation of the descriptive statistics results is illustrated in Table 64.

Determinant			
Hotel Size	**<50 rooms**	**>200 rooms**	**Delta**
n	36	44	
Energy in kWh per RN	59.7	53.9	-9.7%
Water in Liters per RN	363.0	246.9	-32.0%
Hotel Quality	**Midscale**	**Luxury**	**Delta**
n	108	18	
Energy in kWh per RN	42.1	82.2	95.2%
Water in Liters per RN	234.6	437.9	86.7%
Hotel Age	**built >2000**	**built <1950**	**Delta**
n	125	39	
Energy in kWh per RN	53.7	68.3	27.2%
Water in Liters per RN	316.4	360.7	14.0%
Hotel F&B Concept	**Breakfast**	**Full-Board**	**Delta**
n	239	60	
Energy in kWh per RN	48.4	78.2	61.6%
Water in Liters per RN	277.0	435.7	57.3%
Hotel Wellness	**no Wellness**	**Wellness**	**Delta**
n	187	114	
Energy in kWh per RN	38.4	80.1	108.6%
Water in Liters per RN	225.0	436.8	94.1%
Hotel MICE	**no MICE**	**MICE**	**Delta**
n	76	225	
Energy in kWh per RN	38.0	59.7	57.1%
Water in Liters per RN	284.6	313.4	10.1%
Hotel Location	**Urban**	**Rural**	**Delta**
n	139	162	
Energy in kWh per RN	40.9	65.7	60.6%
Water in Liters per RN	251.2	353.6	40.8%
Hotel HVAC	**no Air-Conditioning**	**Air-Conditioning**	**Delta**
n	168	133	
Electricity in kWh per RN	17.4	21.5	23.6%

Table 64: Determinants of Resource Consumption Final Comparison
Source: Author's own data

Various linear regression models are developed to predict annual energy and water consumption demonstrate reliability, as evidenced by the coefficient of R^2, its significance below 5% as well as a VIF below 2 as suggested by the literature. When forming a prediction for total energy and water consumption, the number of floors and rooms, the number of MICE areas, RevPAR, the existence of wellness areas, location as well as water consumption were found to be the most significant. This result corresponds with other studies stating that a hotel's size, level of service, and quality are crucial elements for resource consumption benchmarking (Bohdanowicz and Martinac, 2007; Deyà Tortella and Tirado, 2011; Tsai et al., 2014). Furthermore, it is found that the accuracy of the model increases when similar hotels are grouped together (e.g., 4-star city hotels). Due to its characteristics, the regression tool can be a viable policy instrument easily applied to other hotels and hospitality sectors. However, it has to be acknowledged that the average room number in the data set is 120 rooms, and the regression model to predict total energy and water consumption is more accurate with hotels above 80 rooms.

A comparative analysis of the different research stages reveals additional insights. First, while data on energy and water consumption is available and can be validated, measurements of waste and GHG emissions are still in the early stages. This result is highlighted in previous scientific literature as well as the qualitative stage and becomes even more evident when analyzing data of the quantitative data set. Second, the application of the created intensity metric set in energy and water consumption is validated and replicated in the quantitative analysis. Therefore, using the theoretical intensity metric set is highly practical for day-to-day use in hotel operations. Third, as hotels' characteristics differ substantially, benchmarking must be conducted according to their operational and hardware specifics. The interviewees discussed clustering according to quality level, size, and number of kinds of outlets, which is even more highlighted in the results of the quantitative data set. Results statistically proved the beforehand findings of the experts. To the contrary of the experts' assumptions, it is found that larger hotels (>200 rooms) compared to smaller hotels (<50 rooms) are generally not more energy resource-efficient in intensity values. Moreover, a noticeable disparity emerges between the indicators and the maturity of resource consumption reporting as presented in the scientific literature, legislative frameworks, and current industry practices. To meet the requirements of the recently introduced ESRS regulations, the German and Austrian hotel industry still faces considerable challenges. However, aligning with the UNWTO's recommendation to "*prioritise usability over precision to scale up engagement*" (2023, p. 27), industry experts interviewed in this study underscore the importance of initiating sustainability reporting efforts, even if based on limited data. The findings of this dissertation demonstrate that, despite current gaps, sustainability reporting within the German and Austrian hotel sector is indeed feasible using basic operational data, offering a practical entry point for broader ESG compliance.

7.1. Limitations

This research acknowledges several limitations. The subsequent section delineates both overarching limitations applicable to the entire study and specific empirical limitations observed within the qualitative and quantitative study phases. Generally speaking, the research field is fast-paced and evolved considerably during the elaboration of this research project. For example, legislation fundamentals have changed considerably with the implementation of ESRS in mid-2023. It proved challenging to maintain up-to-date information throughout the study. Consequently, the author attempted to incorporate the latest developments conscientiously.

Within the qualitative study, despite efforts to document the research process to ensure transparency, the categorization of information inevitably bears the influence of researcher bias. To address this concern, the structural dimensions and analytical categories are delineated within the study, with many drawn from previous studies, thereby enhancing rigor and reliability. Furthermore, the selection of interviewees is limited to the German and Austrian hotel industry, reflecting the sector's predominantly SME-based and highly fragmented structure. Another limitation is the limited number of participants caused by the narrowed down research topic. The results are generally satisfactory in the energy and water segment; knowledge is still improvable when it comes to waste and GHG calculations.

The major limitation in the quantitative section is the data availability. First, auditable figures about waste and GHG emissions are not provided, resulting in limited validation of findings of the qualitative phase. Second, the dataset consists of resource consumption data from only one reporting year, making year-on-year changes unobservable. Therefore, the analyzed results represent a temporal snapshot rather than a longitudinal assessment of developments over time. In addition, the collection and analysis of the floor area variable for the hotels included in the dataset would enhance comparability with findings from the SLR and facilitate cross-sectoral comparisons with other asset classes. Third, the sample is not representative of the global hotel industry, given that the German and Austrian hotel sectors are largely composed of small and medium-sized enterprises (SMEs). However, it can be considered broadly representative of the hotel industry within the Central European context. Fourth, as the majority of the data originates from the 2022 business year, residual impacts of the Coronavirus pandemic may have introduced distortions, potentially affecting the accuracy and representativeness of the findings. To overcome this challenge, analysis is conducted using per-guest intensity metrics, minimizing the potential for distorted values compared to per-floor area measurements.

Nevertheless, despite the identification of distinct differentiation characteristics, hotel real estate and operations are inherently complex systems and have therefore been necessarily simplified in the context of this study. Fifth, reliance on a single existing dataset may pose limitations to data quality and generalizability. However, all entries within the dataset were externally audited and are certified by the GSTC, thereby enhancing their credibility.

Additionally, to validate the results and address this limitation, resource data, associated intensity metrics, and regression models are spot-checked using manual direct data from three hotels obtained from the researcher's network. The results indicate that actual consumption is +/- 15% of the predicted regression equation, which is in a similar range to other studies in the same research field (Becken et al., 2001; Priyadarsini et al., 2009; Wang, 2012). Within regression analysis, the established benchmarking models only compare total consumption figures. An initial attempt to develop an intensity ratio benchmarking model yielded a non-significant coefficient of determination (R^2), and as such, the model was not pursued further. Lastly, it must be acknowledged that resource consumption patterns are influenced by a range of additional factors, such as guest behavior and other external variables not explicitly addressed in this study. This is further evidenced by the unexplained variance and the substantial constant term observed in the linear regression models. Lastly, when performing resource consumption benchmarking, it has to be acknowledged that numerous other non-researched influential factors, such as thermal insulation, roofing, type of carpentry, or guest behavior, might influence resource consumption patterns. These considerations necessitate a critical evaluation of the applicability of these indicators for external benchmarking, as their lack of direct comparability can lead to misleading interpretations and hinder rigorous comparisons. To overcome this challenge, a globally uniformed audit and reporting scheme across all sustainability areas is necessary.

7.2. Theoretical and Practical Implications

The findings of this research on resource benchmarking in the hotel industry hold both theoretical and practical significance. From a theoretical perspective, the study contributes to the growing body of literature on sustainable practices within the hospitality sector. By exploring energy benchmarking methodologies and their application in hotels, the research enhances the theoretical understanding of how environmental intensity metrics can be effectively utilized in this context. What is more, by integrating existing industry initiatives with recent European Union legislative frameworks, the study aligns academic inquiry with policy developments. Additionally, the study offers insights into the German and Austrian hotel industry and thus enriching the scientific resource benchmarking with a database of 301 hotels. Furthermore, the use of a mixed methods approach that combines a literature review, expert interviews, and quantitative analysis presents a novel methodological contribution to the field.

On a practical level, the synthesis provides valuable guidance for hotel managers and industry stakeholders seeking to improve resource efficiency with comparable intensity metrics and reduce environmental impact. The identification of best practices values for energy- and water benchmarking allows practitioners to benchmark their own resource consumption against industry peers, identify areas for improvement, and implement targeted strategies to enhance operational efficiency and sustainability. With regard to waste and GHG measurements, the findings form a basis for further research. Identified significant differentiation patterns for hotels enhance the finding of valid peer groups. What is more, mean resource consumption values may be useful for green lease negotiations and the implementation of measurable contract clauses between real estate owners and hotel operators. Furthermore, the encountered helps in better understanding potential sources of energy and water inefficiencies and aids in the selection and design of mitigation measures. Ultimately, the theoretical and practical implications of this study contribute to the advancement of sustainable practices in the hotel industry, facilitating informed decision-making and promoting environmental stewardship within the sector. To summarize, the following practical recommendations for action are identified:

Implement Intensity Metrics in Hotel Operations:

Hotel managers should integrate the identified intensity metrics for EGWW consumption into their routine operational practices for the purpose of internal benchmarking. This approach enables more efficient resource utilization, contributing to cost reduction, and facilitates meaningful comparisons with industry benchmarks. Among these metrics, energy and water consumption are the most readily measurable and trackable, making them particularly suitable for consistent monitoring and performance evaluation.

Benchmarking and Best Practices:

Hotel managers should use the best practice values for energy and water benchmarking to assess their resource consumption. By comparing against industry benchmarks, they can identify inefficiencies and implement targeted strategies for improvement. As a starting point, differentiating location, hotel size, F&B concept, existence of wellness area and according to quality level (star-rating) is advisable.

Green Lease Agreements and Contract Clauses:

The study's findings should be used by hotel managers and real estate owners to negotiate green lease agreements with measurable sustainability clauses, ensuring both parties are committed to achieving specific sustainability goals.

Investment in Retrofitting and Technology:

Hotels should prioritize investment in energy-efficient technologies, such as LED lighting, water-saving devices, and HVAC system improvements. Retrofitting older buildings should be a key focus to improve overall resource efficiency. Furthermore, the procurement of certified green electricity constitutes a highly effective and easily implementable strategy for reducing greenhouse gas emissions in hotel operations.

Collaboration with Stakeholders:

Hotel operators should collaborate with industry stakeholders, including investors, local governments, and regulatory bodies, to promote adopting sustainability standards, furthering the development of an industry-wide approach to environmental performance and resource efficiency.

To conclude, this study contributes by cataloging intensity metrics, clustering audit results, and offering insights for environmental performance improvement, sustainability policy enhancement, and regulatory compliance within the hotel industry. However, it acknowledges the exploratory nature of research integrating environmental concerns into hotel operations. These findings serve as a valuable resource for hotel managers, investors, and government authorities alike, guiding efforts to establish environmental conservation standards within the hospitality industry.

7.3. Directions for Future Research

Despite the frequent discourse on environmental sustainability, much remains to be explored in this field, particularly within the tourism and hospitality sector, where environmental impacts are significant. To delve deeper into hotel resource consumption patterns, further investigations are necessary. This includes selecting representative hotels for inter-group comparisons and installing digital energy and water meters for major equipment to obtain quantitative evidence on resource usage. Furthermore, future studies should also be replicated in a different geographical setting or just focus on a specific kind of hotel with similar characteristics (e.g., 4-star city hotels, 5-star countryside hotels). The latter is advisable to achieve a higher R^2 and thus improve the accuracy of resource consumption prediction in the hotel real estate. Expanding research on other influencing factors, such as guest behavior, building material used, and zoning of resource consumption outlets, to reduce the high constant term and increase explained variance when implementing linear regression models. There, the decomposition in major end-users' seems purposeful equally to assess the usage of the resources in more detail. Furthermore, possible climatic differences in Germany and Austria and their effects on resource consumption have not been analyzed, leaving room for further research. Building on the findings of the ANOVA analysis, further grouping of independent variables may enhance the explanatory power of the model, potentially yielding a higher R^2. Additionally, investigating non-linear relationships and utilizing machine learning techniques could improve predictive accuracy. Given that interaction effects indicate certain variables influence energy consumption independently, future research should also explore potential moderating or mediating effects, particularly in relation to operational efficiency and management practices. Furthermore, as outlined in the limitations section, a time series analysis examining and comparing multiple reporting years could provide deeper insights into the effectiveness of measures that contribute to reducing resource consumption.

With regards to waste measurements in the hotel industry huge potential for further research is identified. For example, the drivers for waste production and segments or waste volume per specific stakeholder can decrease total waste consumption. As elaborated in the study, the implementation of a unified waste weighting system would enhance external benchmarking. The creation of benchmarks based on quantitative data can support the numerous recommendations on waste management. Furthermore, future studies could be replicated in the context of sustainable tourism destination management by examining the link between sustainability and tourists' travel journeys. This could involve assessing the use of more sustainable transportation options and subsequently proposing new environmental indicators, which would help to elucidate the way towards Scope 3 footprint. Especially with GHG emissions measurement, a consensus around boundaries and measurement responsibilities is needed. Within this context, the HCMI industry framework is identified during the qualitative expert phase as a solid foundation for measuring GHG emissions. However, further qualitative and quantitative validation is necessary, particularly in the context of the Central European region.

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9. Appendix

Due to the extensive volume of the Appendix, certain sections are stored in a freely accessible cloud storage. If the provided links are not functional, please contact the following email: dissertation.schick@gmail.com

A Consent Form Expert Interview

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Information zur Erhebung und Verarbeitung personenbezogener Daten

Sehr geehrte_r Interviewpartner_in!

Im Rahmen meines *Doktorats*-Studiums an der Fakultät Bauingenieurwesen an der Technischen Universität Wien (in der Folge kurz als „TU Wien" bezeichnet) arbeite ich gerade an meiner *Dissertation*. Das Verfassen dieser wissenschaftlichen Arbeit ist mit der Erhebung und Verwendung personenbezogener Daten verbunden. Die Verarbeitung personenbezogener Daten hat in Entsprechung der geltenden Datenschutzbestimmungen zu erfolgen, daher darf ich gemäß Art 13 Datenschutz-Grundverordnung (DSGVO) über die Datenverarbeitung informieren wie folgt:

Verantwortliche_r für die Datenverarbeitung

1. Interviewer_in, Verfasser_in der *Dissertation* und Verantwortliche_r für die Datenverarbeitung iS von Art 4 Zif 7 DSGVO

   Alexander Schick, alexander.schick@ifm.tuwien.ac.at

Gegenstand der Dissertation

1. Titel der *Dissertation*
   „Development of environmental intensity indicators for the hotel industry – formation, analysis and identification of dependent consumption variables within the DACH region"

Art der verarbeiteten personenbezogenen Daten

Folgende personenbezogene Daten zu Ihrer Person werden im Rahmen meiner wissenschaftlichen Arbeit verarbeitet:

persönliche Angaben, nämlich insbesondere

- berufliche Tätigkeit,
- Geschlecht,
- Berufsjahre

Aufnahmen: Tonaufnahmen

Zweck der Datenverarbeitung

Auswertung von Interviews zum Thema Nachhaltigkeits-Intensitätsindikatoren für die operative Phase des Hotels und Verarbeitung der erhobenen Daten im Rahmen meiner Dissertation.

Beschreibung der Datenverarbeitung

Das Interview wird mit einem Tonaufnahmegerät aufgezeichnet und anschließend in Schriftform gebracht. Für die weitere Auswertung der Interviewtexte werden alle Angaben, die zu einer Identifizierung der Person führen könnten, pseudonymisiert oder aus dem Text entfernt. In der Dissertation werden Interviews nur in Ausschnitten zitiert, um gegenüber Dritten sicherzustellen, dass der entstehende Gesamtzusammenhang von Ereignissen nicht zu einer Identifizierung der Person führen kann. Personenbezogene Kontaktdaten werden von Interviewdaten getrennt für Dritte unzugänglich aufbewahrt.

Rechtsgrundlage

Die Rechtsgrundlage zur Verarbeitung dieser personenbezogenen Daten stellt Art 6 Abs 1 lit c DSGVO in Verbindung mit § *83 für Dissertationen* UG dar.

TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

Art 6 Abs 1 lit c DSGVO normiert die Verarbeitung personenbezogener Daten zur Erfüllung einer rechtlichen Verpflichtung, der die_der Verantwortliche unterliegt. §§ 80ff UG stellen die rechtliche Verpflichtung dar. Es wird je nach Art der wissenschaftlichen Arbeit unterschieden: § 80 UG betrifft die Bachelorarbeit (Art 6 Abs 1 lit c DSGVO iVm § 80 UG); § 81 UG betrifft Diplom- und Masterarbeiten (Art 6 Abs 1 lit c DSGVO iVm § 81 UG); § 83 UG betrifft Dissertationen (Art 6 Abs 1 lit c DSGVO iVm § 83 UG). Die datenschutzrechtliche Rechtfertigung für die Verarbeitung der Daten ist nicht die Einwilligung der Betroffenen.

Übermittlungsempfänger_innen und Drittstaatenübermittlungen

Grundsätzlich haben nur autorisierte und zur Verschwiegenheit verpflichtete Personen im Zuge der Erarbeitung und Betreuung der *Dissertation* Zugang zu den verarbeiteten, personenbezogenen Daten, und dies nur in dem erforderlichen Umfang. *Die Daten werden nicht an Dritte weitergegeben.*

Speicherdauer

Zum Nachweis der guten wissenschaftlichen Praxis sowie für die Nachprüfbarkeit der gewählten Methode und der erzielten Ergebnisse, wird die Protokollierung und die Dokumentation des wissenschaftlichen Vorgehens auf haltbaren und gesicherten Datenträgern gespeichert. Dies erfolgt datenschutz-konform und gegenüber Dritten unzugänglich. Die Datenspeicherung richtet sich nach den gesetzlichen Bestimmungen und erfolgt entsprechend § 2f Abs 3 Forschungsorganisationsgesetz (FOG) für die Dauer von maximal 30 Jahren.

Betroffenenrechte

Gemäß der DSGVO stehen Ihnen als betroffene Person folgende Rechte zu:

- Recht auf **Auskunft** über die betreffenden personenbezogenen Daten (Art 15 DSGVO)
- Recht auf **Berichtigung** (Art 16 DSGVO) oder **Löschung** (Art 17 DSGVO) oder auf **Einschränkung** der Verarbeitung (Art 18 DSGVO) unter den in den angeführten Bestimmungen beschriebenen Voraussetzungen
- **Recht auf Beschwerde**, welche bei der Österreichischen Datenschutzbehörde, Barichgasse 40-42, 1030 Wien, Telefon: +43 1 52 152-0, E-Mail: dsb@dsb.gv.at als zuständige Aufsichtsbehörde einzubringen ist.

Artikel 11 DSGVO sieht zudem vor, dass eine separate Rückführbarkeit von Daten auf Personen nicht gewährleistet werden muss, nur um die Betroffenenrechte wahren zu können.

Zur Geltendmachung Ihrer Rechte wenden Sie sich an mich wie folgt:

Alexander Schick
Elisabethstraße 24/16, 1010 Wien
Österreich

Hiermit bestätige ich, dass ich über das Forschungsvorhaben ausreichend informiert wurde und dass offene Fragen meinerseits von dem Forscher zu meiner Zufriedenheit beantwortet wurden. Es ist mir bewusst, dass meine Teilnahme an der Datenerhebung freiwillig ist und ich diese jederzeit ohne Angaben von Gründen beenden kann. Ich bin damit einverstanden, dass das Interview aufgezeichnet wird und später in Schriftform übertragen werden kann. Ich wurde darüber informiert, dass meine Aussagen in wissenschaftlichen Arbeiten und Publikationen anonymisiert zitiert werden können.

....

Ort und Datum Name und Unterschrift

B Qualitative Questionnaire

Semi-structured Interview Guide

Please note: This questionnaire was used as a basis for structured discussion and was not provided to the interview participants.

Part 1: General Questions

What is your position in the company?

How long are you working in this kind of position?

What brought you to sustainability?

In case of an investor or hotel company: Talk a bit about your portfolio.

Part 2: Research Project Explanation

My research focuses on developing valid intensity indicators for the specific sectors of energy, water, waste, and GHG emissions within the hotel industry, with an emphasis on their application in the environmental dimension of ESG (Environmental, Social, and Governance) criteria. A key issue identified is that major hotel chains continue to report environmental data in highly inconsistent and divergent ways. An intensity indicator typically consists of an input variable divided by a reference variable, with a corresponding a time unit. For instance, in the context of a hotel, this could be measured as kilowatt-hours (kWh) of energy consumption (input) per guest room (reference unit) per year (time unit). Upon analyzing the reporting practices of large hotel corporations, a noticeable discrepancy in the data reported is already apparent.

Part 3: Environmental Practices

What are you measuring in terms of environmental sustainability?

Have you thought about intensity indicators to measure resource consumption in the past?

What indicators to measure resource consumption in the hotel industry do you know?

Energy

Water

Waste

GHG

Part 4: Generating Indicators

Input Variables

Which input variable needs to be taken into account to generate a valid indicator?

Energy:

Total energy consumption, gas, thermal, fuel

Renewable energy share (e.g., Green Gas)

Own produced electricity (e.g., solar power)

Vehicle fuels

Outsourced energy consumption

Water:

Total water withdrawal

Municipal water

Grey Water

Other water

Outsourced laundry

Garden / Bewässerung

Waste:

Landfill

Recycled waste

Composted waste

What kind of waste are you separating? Should be separated especially to have a unified system in German and Austrian hotel industry?

GHG: CO2-e, Scope 1, Scope 2, Scope 3

GHG calculation tool

Reference Variables

Which reference variable is a valid measurement for the hotel industry?

Energy

Water

Waste

GHG: CO2-e, Scope 1, Scope 2, Scope 3

Examples:

per floor area (e.g., square meter)

per room

per occupied room

per guest night

per person

per cover

Any other reference variable you can think of?

Units of Measurement

Which unit is a valid measurement?

Energy:

MWh

kWh

MJ

Water:

Liter

m^3

kg

Waste:

Kg

liter

GHG:

CO2-e

Scope 1

Scope 2

Scope 3

GHG: what calculation schemes do you know? What is mostly used in the hotel industry? Which scopes should be covered?

Is collecting Scope 3 emissions already possible?

Any other input variable you can think of?

Time unit

What time unit is achievable in the day to day business to track the indicator?

Daily

Monthly

Quarterly

Yearly

Is the data easily available in hotels?

Part 5: Clustering

Should the hotels be clustered to gain valid benchmark values? If yes, according to which principles?

Operational? Physical Factors / Real Estate Characteristics. Examples:

Star-rating / Quality level of hotel

Outlets of hotel

Occupancy level / number of guests

Location and Climate

Age of building

Construction material used

Nationalities

Historic Protection

Chain Affiliation

Outsourced laundry

Gardening

Should the outlets be differentiated (e.g., public spaces and room spaces?)

In summary: What is the most important intensity indicator in each category for the hotel industry?

Anything else to add to the discussed topics?

Thank you for your time!

C Interview Transcripts

Interview Respondent 1

https://drive.google.com/file/d/1wBxB8zD9kRrn2UZrw_4PAg9UZOFk0eOK/view?usp=sharing

Interview Respondent 2

https://drive.google.com/file/d/1XdMwh1DNACTvtBM8ExVzs2Ng4iXwnxCU/view?usp=sharing

Interview Respondent 3

https://drive.google.com/file/d/1u-IYMbKsEQB9P_kJM_fjAPWJhrg4ZfIJ/view?usp=sharing

Interview Respondent 4

https://drive.google.com/file/d/1ssBZ_FYOgpFTXrAJiJjwM7Pxtl8kl8qm/view?usp=sharing

Interview Respondent 5

https://drive.google.com/file/d/10ypO8aNyexxlo--EYSNipjAAI1JZjGJX/view?usp=sharing

Interview Respondent 6

https://drive.google.com/file/d/1DrG-IXc3ttrrzHw1ZRDycJK7spggg0HV/view?usp=sharing

Interview Respondent 7

https://drive.google.com/file/d/1feqJ9L3SHLeqP9-g48UFbmQcLddp8tEq/view?usp=sharing

Interview Respondent 8

https://drive.google.com/file/d/17Qt1tcmXS3pTpkN6SOJ4kQdggNtuLRFM/view?usp=sharing

Interview Respondent 9

https://drive.google.com/file/d/1a5yjd5yKpK0Z0jU6jvHvqm4-2rBd5Aqp/view?usp=sharing

Interview Respondent 10

https://drive.google.com/file/d/10CplJAzcMFTEn4DtWT09sS4p9mQPEaHz/view?usp=sharing

Interview Respondent 11

https://drive.google.com/file/d/1GPB4TZxhkwF3MQktie7vw8Gits768RCD/view?usp=sharing

Interview Respondent 12

https://drive.google.com/file/d/1VScFxBsvGnF6zQgeZzBR1Hr8x3XFad4q/view?usp=sharing

Interview Respondent 13

https://drive.google.com/file/d/1JpWgruE_dZWRqPbmrZWtFpwzNKXTWToG/view?usp=sharing

Interview Respondent 14

https://drive.google.com/file/d/1ZW6EOJ45EuWvrI_wCrtibtbjSZolekIg/view?usp=sharing

Interview Respondent 15

https://drive.google.com/file/d/1ygAyyxrUlDnbvfL4WbteTQKIXCE1Un2s/view?usp=sharing

Interview Respondent 16

https://drive.google.com/file/d/15kWuCXfnob6JzMqCh8yblMTL5sunFAVf/view?usp=sharing

D Codebook Qualitative Phase

https://docs.google.com/spreadsheets/d/1SjhcP-n4K8_evAGb9H-ZkQS6pZcQiZzQ/edit?usp=sharing&ouid=112079809452175412790&rtpof=true&sd=true