UNIVERSITY OF TURKU

Exploring the Adoption Rate of ISO 50001 in the Finnish Industry

A Comparative Analysis with Germany

Mechanical Engineering/ Department of Mechanical and Materials Engineering

Master's thesis

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Abstract

This study examines the adoption of ISO 50001 in the Finnish industrial sector, comparing it with Germany to understand the implementation gap. Drawing from data collected through the European Manufacturing Survey (EMS) consortium and a comprehensive literature review, the research investigates the drivers, barriers, and implications of ISO 50001 certification. Key findings reveal a significant disparity in adoption rates between Germany and Finland, with Germany exhibiting a penetration rate over 1600% higher than Finland. While financial incentives, environmental responsibility, and alignment with corporate strategy emerge as key drivers for adoption, challenges such as limited financial resources, weak leadership commitment, and cultural barriers hinder implementation efforts. The study underscores the importance of targeted policies and initiatives to address barriers and promote ISO 50001 adoption. Additionally, insights from case studies demonstrate substantial reductions in energy consumption and greenhouse gas emissions post-certification, highlighting the potential for significant environmental and financial benefits. Suggestions for further research include expanding the sample size, exploring the impact of direct incentives on adoption, comparing it with other energy management standards, and conducting longitudinal studies on energy performance. By pursuing these avenues, organizations can enhance their energy management practices, reduce environmental impact, and realize long-term cost savings

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1 Introduction

This thesis is done within the European Manufacturing Survey (EMS) consortium, at the University of Turku. The European Manufacturing Survey (EMS) serves as an invaluable platform for capturing perspectives from the broader European Manufacturing Community on future manufacturing priorities beyond 2030. This survey encompasses essential indicators focusing on innovation areas such as the "technical modernization of value-adding processes," "introduction of innovative organizational concepts and processes," and "new business models for complementing the product portfolio with innovative services." These indicators, collectively agreed upon by the EMS consortium, are systematically surveyed across all participating countries. Moreover, specific questions on diverse topics are included by some countries, aligning with the overarching goal of the survey's question design. This design aims to maintain a consistent set of common questions across multiple survey rounds, adapt other shared questions to address current issues in the field of production innovations, and allow for the inclusion of country or project-specific topics.

Typically conducted as a written survey at the company level in most countries, EMS employs a joint validation and harmonization procedure for national data to facilitate multinational analyses. This collaborative approach ensures the comprehensive and detailed exploration of manufacturing trends and priorities within the European context. The most recent survey in Finland, conducted in 2022 by Professor Jussi Kantola and Janne Heilala, forms the foundation for the selection of the thesis topic. This choice is informed by a thorough analysis of the survey results within the Finnish industrial landscape. This data is collected from a questionnaire that covers 26 different aspects including questions concerning energy management systems and ISO certifications. One of the ISO certificates has a direct connection to the energy management system which is ISO 50001. The ISO 50001 standard is primarily concerned with establishing the specifications for an energy management system (EnMS) that would enable the business to methodically work toward continuous improvement of energy efficiency while taking into consideration any applicable legal obligations.

On the flip side, implementing an energy management system doesn't automatically ensure that a manufacturing company meets the standard requirements. This gap could result in a scenario where manufacturers use the EnMS but fail to fully harness its potential unless a continuous improvement approach, at the heart of ISO 50001, is considered. The process of

implementing standards requires certain catalysts, and it also faces challenges and barriers that need a thorough examination to streamline the implementation. This gap is a main driver and motivation for this thesis and to give some insights about the level of adaption rate, a comparison with Germany as one of the leading countries in manufacturing in Europe is done. In addition, the reason behind this gap is also studied by literature conduction literature review.

2 Literature reviews

2.1 Procedure:

This section of the thesis aims to provide an overview of the general method of searching and reviewing previous studies conducted on the subject. The overall conceptual framework is illustrated in Figure 1.

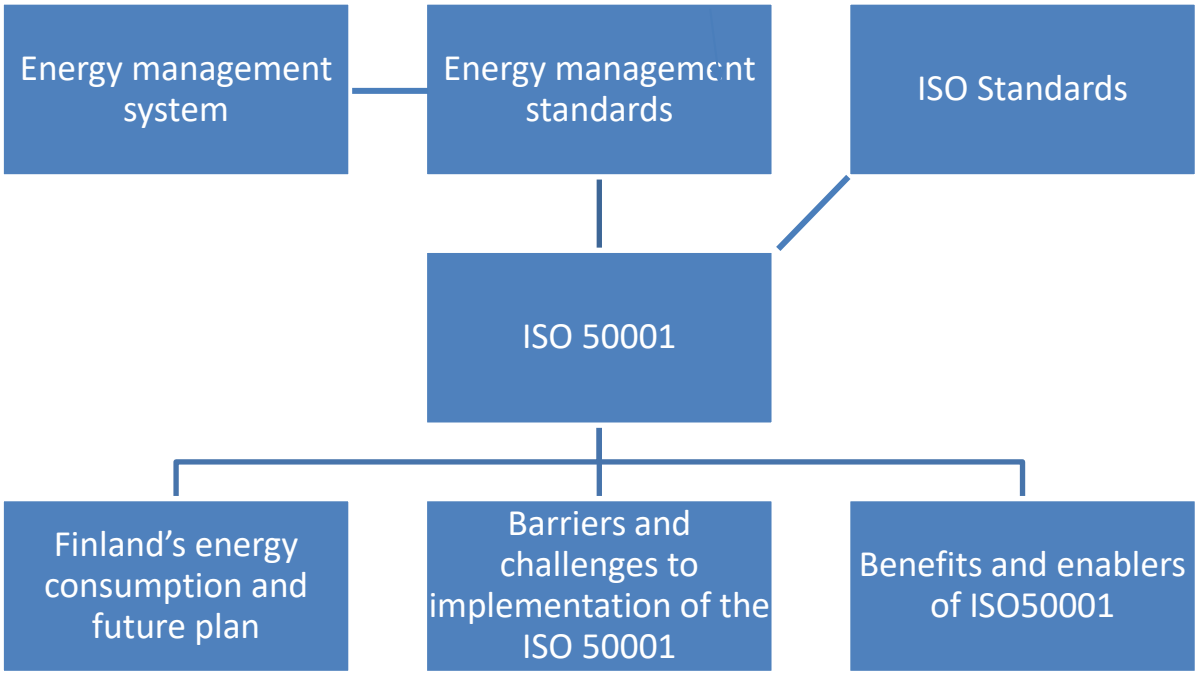


Figure 1: Literature review conceptual framework

2.2 Energy Management System (EnMS)

An energy management system is a collection of connected or cooperating parts in a plan that establishes an energy efficiency goal and a plan of action to reach that goal. It is also defined as a formalized framework that outlines the objectives, rules, and methods for maintaining and enhancing them (Gopalakrishnan et al., 2014). Enhancements can be made in three areas of energy management: people, technology, and results assessment. People's culture and behavior change when the energy management system is implemented and these changes are accompanied by training and responsibility-setting. The best (energy-efficient) technologies are chosen for the deployment of an energy management system with eco-design to ensure proper operation and maintenance. Implementing energy management results in performance

evaluation using statistics and data analysis. The "plan, do, check, act" principle describes these procedures(Beihmanis & Rosa, 2016).

2.3 Energy management standards

In recent years, numerous countries have formulated national standards for energy management, sharing a common structure rooted in the plan-do-check-act cycle. These standards primarily aim to incentivize businesses and industries to establish robust systems and processes for energy management, ultimately leading to reductions in energy costs and greenhouse gas emissions. However, the challenges associated with meeting the objectives of these national standards vary. Among the national level standards, there are three main international standards: the American standard ANSI/MSE 2000 and the European standard EN 16001 and ISO 50001 standard—incorporate elements of strategic management, with the American standard providing a more detailed reflection. The majority of standards, including the International Standard for Energy Management ISO 50001, predominantly focus on addressing issues within operational management. The main difference among these standards is the geography applicability where ANSI/MSE 2000 is meant for the USA territory EN 16001 is aimed at the European Union and ISO 50001 is an international standard(Anisimova, 2013).

2.4 The ISO 50001 standard

The ISO 50001 standard is primarily concerned with establishing the specifications for an energy management system that would enable the business to methodically work toward continuous improvement of energy efficiency while taking into consideration any applicable legal obligations. When it comes to energy-intensive industries or when it's necessary to comply with rules and regulations about greenhouse gas emissions, the energy management system is very crucial. The standard may operate separately or in conjunction with other management systems (Zimon et al., 2021). The main constituents of the ISO 50001 are represented in Figure 1 which is also connected with the Plan-Do-Check-Act (PDCA) cycle concept (Iñaki Heras-Saizarbitoria, 2018).

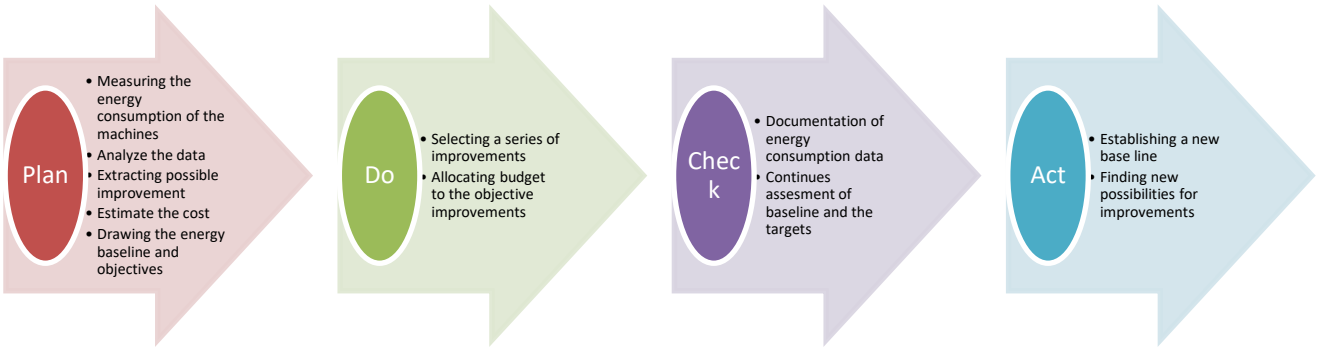


Figure 2 PDCA cycle concept for ISO 50001

It is worth noting that ISO 50001 was first published in 2011 and then revised in 2018. The 2018 update of ISO 50001 aimed to make it match ISO's overall management system standards. They introduced a framework called the High-Level Structure (HLS) to help smoothly include new management topics in existing systems. Changes in the updated version include a stronger focus on senior management's role, clearer terms and definitions, and better explanations for energy performance indicators (EnPI) and energy baselines (EnB). These changes were made to make it easier for people to understand and use these concepts(ISO organization, 2018). ISO technical committee continuously developed other standards related to the ISO 50001 to complete the energy management standard family. In Table 1 these standards with their scope are presented(ISO organization, 2018).

Table 1 The ISO 50001 family

Standard name	Scope	Description
ISO 50002	Energy audits	Requirements and guide for use
ISO 50003	EnMS	Requirements for bodies
ISO 50004	EnMS	Instruction for executing, sustaining, and enhancing implementations.
ISO 50006	EnMS	Guideline to measure energy performance using EnB and EnPI
ISO 50007	Energy Services	Guidelines for evaluating and enhancing the energy service provided to users
ISO 500015	EnMS	Principles and guidance for the overall measurement and validation of energy efficiency in organizations.
ISO 500047	Energy saving	Identification of energy conservation.

2.5 The ISO 50001 implementation main drivers and benefits

There were around 14 local and/or regional energy management standards before ISO 50001, which share many common features. This is because they were developed by people who followed the ISO management model for continuous improvement. However, ISO 50001 has significant improvements, particularly when compared to the European Energy Standard EN 16001:2010. Its structure is based on other ISO management system standards, such as ISO 9001 and ISO 14001, and it follows the Plan-Do-Check-Act (PDCA) cycle. As a result, ISO 50001 can be easily integrated into these management systems (Marimon & Casadesús, 2017a). The main motivation for organizations to implement an energy management system (EnMS) is the potential for cost savings, which can reach up to 10% in the first years after implementation. Investments in certain areas, such as compressed air systems and cooling, can reduce power consumption by up to 50% and pay for themselves within two years (Fiedler & Mircea, 2012). In some countries, EnMS certification can also lead to government incentives such as lower taxes and fees. Additionally, implementing an EnMS can contribute to protecting the environment and reducing the risk of natural disasters caused by climate change. Furthermore, having an EnMS can also help a company stay competitive in the future by using sustainable energy technologies, improving its image, and meeting ecological criteria for public calls for bids (Fiedler & Mircea, 2012).

Heidi Fuchs discovered common drivers for the implementation of ISO 50001. These drivers include the desire to obtain certification, improve energy management, reduce energy costs, align with corporate strategy, and access financial support and subsidies (Fuchs et al., 2020a). In Table 2 some of the reported energy savings that have been achieved by companies are presented.

Table 2: Case studies on ISO 50001 implementation effects

Industry	*Effect of implementation*	*reference*
Cement plant	25% reduction in energy consumption	(Pelser et al., 2018)
Social building stock	15% reduction in energy consumption	(Dall'O' et al., 2020)

Industry	*Effect of implementation*	*reference*
Administrative buildings	20% reduction in energy consumption	(El Majaty et al., 2023)
Dairy	50% reduction in CO_2 emission	(Trubetskaya et al., 2023)
Car manufacturing	15% reduction in energy consumption	(Elizabeth Gasiorowski-Denis, 2012)
Hotel	20.6% in energy and 30% in CO_2 emission reduction	(Elizabeth Gasiorowski-Denis, 2018)
Cloud service	15% reduction in energy consumption	(Elizabeth Gasiorowski-Denis, 2016)
Foundry Industry	8.7% reduction in energy consumption	(Chaves et al., 2020)
Building	reducing energy consumption by 613.188 kWh	(Kurniawan & Feinnudin, 2021)
University Building	31.36% reduction in energy consumption	(Pasvorarotkool & Mongkon, 2020)
Public Building	12% reduction in energy consumption	(Jekabsone et al., 2020)
Water industry	3.2% reduction in energy consumption	(Shin, 2021)

In addition to some study results which are presented in Table 1, P. Fitzgerald et. al investigated the energy performance of 83 manufacturing companies after the implementation of ISO 50001. The results showed that these companies' energy consumption reduced by 4.1% on average after the first year of the implementation and 3.4% for the next twelve years of implementation which shows, the persistence of the effect of the adoption for a long period(Fitzgerald et al., 2023).

It is worth noting that although the reduction in energy consumption and CO_2 are important, as mentioned earlier, there are other drivers for the implementation of the ISO 50001. These drivers have been investigated in a few literatures. To summarize the main findings through the previous studies and literature about the main drivers and motives, these drivers are listed in Table 3. Due to the fact that ISO 50001 is a relatively new standard compared to ISO 14001, some literature suggests that the motives and drivers for both standards may be the same or at least can be considered as a starting point for the investigation.

Table 3 : Driver and motives for implementing an EnMS standard.

Row No.	*Driver/Motive*	*ISO type*	*Reference*
1	energy saving and costs	50001	(Boer, 2022; Fuchs et al., 2020a)
2	greenhouse gases emission reduction	50001	(Boer, 2022; Fuchs et al., 2020a)
3	Environmental sustainability	50001	(Fuchs et al., 2020a)
4	Government incentives or regulations	50001	(Fuchs et al., 2020a)
5	Competitiveness	14001, 50001	(Boer, 2022; Marimon & Casadesús, 2017b)
6	Ecological responsibility	14001, 50001	(Boer, 2022; Marimon & Casadesús, 2017b)
7	Legitimation	14001	(Marimon & Casadesús, 2017b)
8	Social pressure	9000	(Boer, 2022; Neumayer & Perkins, 2005)
9	Improving efficiency	9000	(Boer, 2022; Neumayer & Perkins, 2005)
10	Improving corporate image	14001, 50001	(Pan, 2003) , (Fuchs et al., 2018)
11	Environmental improvement	14001	(Boer, 2022; Pan, 2003)
12	Gaining marketing advantage	14001	(Pan, 2003)
13	Improving relations with communities	14001	(Pan, 2003)
14	Avoiding development risk motive	50001	(Boer, 2022)
15	Government support seeking	50001	(Boer, 2022)
16	Technology advancement motive	50001	(Boer, 2022)
17	Departmental performance motive	50001	(Boer, 2022)
18	Rising energy costs	50001	(Boer, 2022)
19	Energy security	50001	(Boer, 2022)
20	Market competition	50001	(Boer, 2022)

Reddy B. suggested categorizing the drivers and motives for adopting an EnMS into two segments, internal drivers, and external drivers. Combining Reddy's approach and the extracted driver from other literature gives a better scheme for the drivers and motivators for ISO 50001 implementation. This scheme is presented in figure Figure 2.

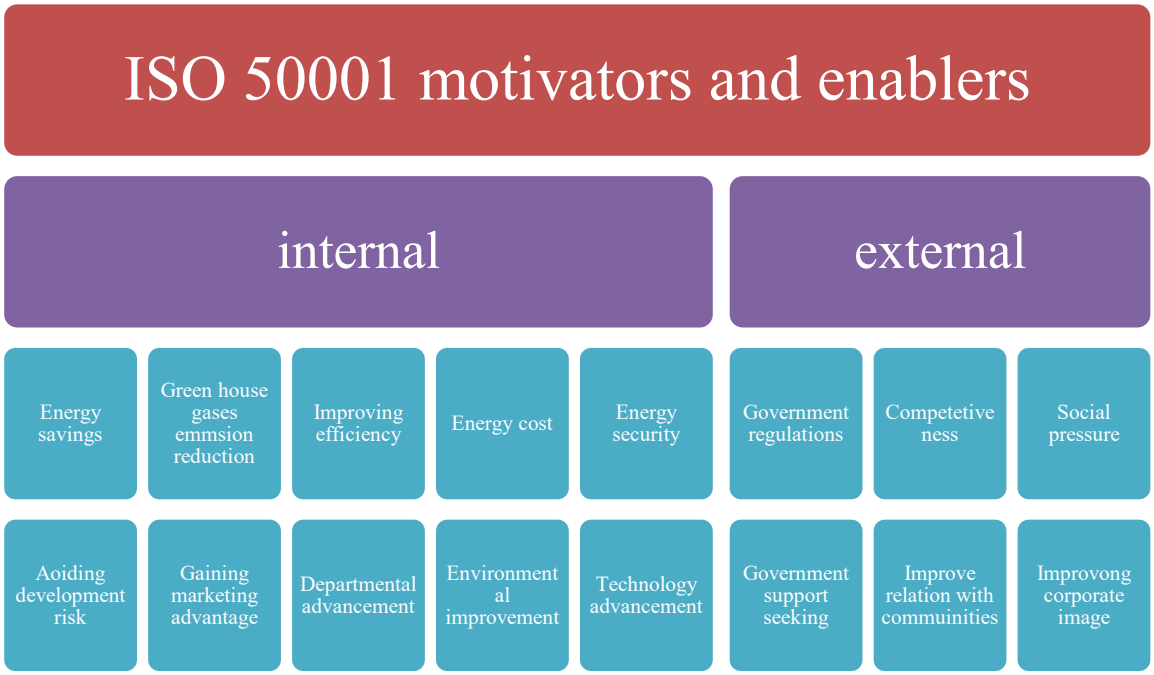


Figure 3 ISO 50001 implementation motivators and enablers

2.6 Effect of implementation of ISO 9001 and 14001 on the implementation of ISO 50001

J. Sousa Lira et al. surveyed the possible influence of the earlier developed ISO management systems including ISO 9001 and ISO 14001 which are quality management system standards (QMS) and Environmental Management Systems (EMS) respectively, on the diffusion of the ISO 50001in the different region on the world. They found out there are positive correlations in some regions between the level of adoption of these two standards and the adoption of ISO 50001(Sousa Lira et al., 2019). From this study's perspective, this should be considered as a potential facilitator or enabler for the adoption of ISO 50001.

2.7 Implementation challenges, barriers, and obstacles

Since the primary aim of this study is to determine the causes of the low number of certified companies in the Finnish industry, potential obstacles have been identified by examining other published materials. Jan Kaselofsky has extracted different parameters from publications worldwide. The article provides a summary of various publications that explore the challenges and obstacles that hinder the implementation of an ISO 50001 energy management system. The study reveals the primary barriers as limited financial, technical, and personnel resources, weak leadership commitment, data management difficulties, and human resource deficiencies. Other impediments include missing or incomplete data, a lack of energy managers, difficulty in identifying energy efficiency measures, and the need for appropriate software for monitoring energy data. The publications highlight the significance of incentives from the government, increased energy efficiency, and employee awareness of energy-use behavior as motivational factors for setting up an ISO 50001 energy management system. Moreover, respondents rated ecological benefits of energy savings and better environmental performance higher than production benefits such as productivity and process optimization (Kaselofsky et al., 2021). Another critical challenge in the certification of ISO 50001, is from the audit side. Auditors may need special knowledge, skills, and tools to measure and verify compliance (Iñaki Heras-Saizarbitoria, 2018). Samarakoon et al. found the same issue about the level of adaption of ISO 50001 in Sri Lanka and survey to reveal the probable barriers. They reveal that in addition to earlier mentioned barriers, unawareness of the importance of applicability and different cultural aspects also affects the implementation process(Samarakoon & Rajini, 2013). In a study that has been done by H. Fuchs et. al to identify the barriers and challenges of ISO50001 through case studies, lack of support from top management, organization culture toward energy management system, imperfect information, and insufficient energy consumption data, Limited employee awareness about the benefits, Existing gap and inconsistency between different departments, insufficient budget allocation for implementation and the lack of time commitment have been reviewed(Fuchs et al., 2020b). Top management support, energy awareness culture, and the possibility of collecting energy consumption data are mentioned as the most important keys to successful implementation.

2.8 Energy Consumption Overview in Finland

Energy management is of great importance in Finland's industry sector due to its high energy use and contribution to the country's overall energy consumption. As revealed by the statistics, the industry sector consumed 131,803 GWh of energy in 2022, which is almost half of the total energy consumption in the country (stat.fi, 2023). With such high energy consumption, the industry sector must prioritize energy management to mitigate the negative impacts on the environment and reduce their energy costs. Additionally, with Finland's per capita energy consumption being higher than other European nations due to its frigid climate and energy-intensive industry, efficient energy management practices can help the industry sector become more sustainable and competitive in the market (Tabasi et al., 2018). Therefore, implementing effective energy management strategies can not only help the industry sector reduce its carbon footprint but also improve its economic performance.

2.9 Finland Program for Carbon Neutrality

As per the Government Program, Finland has set a target to become climate-neutral by 2035 and establish the world's first fossil-free welfare society. To achieve this, emissions caused by human activities must be balanced by the sinks that sequester carbon. According to the EU law, Finland is obligated to decrease the greenhouse gas emissions of the effort-sharing sector (non-ETS) by 39% by 2030, in comparison to the levels in 2005. The implementation of the new Climate Change Act in 2022 helps in achieving this target by setting emission reduction targets for 2030, 2040, and 2050 and ensuring that the carbon neutrality target for 2035 is met. The scope of the Act was broadened to include the land use sector's emissions, such as forestry, agriculture, and land use, and prioritizes enhancing carbon sinks. The Finnish Climate Change Panel suggested emission reduction targets of -60% by 2030, -80% by 2040, and at least -90%, aiming for -95% by 2050, relative to the levels recorded in 1990. These targets serve as a foundation for national efforts in combating climate change in Finland according to the state treasury (STATE TREASURY, 2023). To improve energy efficiency in the industrial sector, one solution is to adopt ISO 50001, which can regulate and streamline the process.

3 Research implementation and methodology

3.1 Research Objectives:

it's important to set out the main aims guiding the study before we get into the details of the research goals. We're mainly looking into why ISO 50001 isn't widely used in Finnish industries. Here are the research objectives:

- To identify the reasons for the low adoption of ISO 50001 in the Finnish industrial sector.
- To compare the utilization of ISO 50001 in the Finnish and German industrial sectors.
- To explore the relationship between the establishment of energy management systems and certification of ISO 50001 in the Finnish industrial sector.
- To suggest measures for promoting the adoption of ISO 50001 in the Finnish industrial sector.
- To prioritize the implementation challenges

3.2 Hypotheses:

Below are, educated guesses about the factors influencing ISO 50001 adoption in Finnish industries. These hypotheses will guide our investigation into understanding the dynamics of ISO 50001 adoption within this sector.

H1: Lack of awareness and knowledge about ISO 50001 is a major reason for the low adoption of ISO 50001 in the Finnish industrial sector.

H2: The adoption of ISO 50001 is positively correlated with the establishment of energy management systems in the Finnish industrial sector.

H3: The utilization of ISO 50001 in the German industrial sector is higher compared to the Finnish industrial sector.

H4: Providing financial incentives and promoting awareness about the benefits of ISO 50001 can promote the adoption of ISO 50001 in the Finnish industrial sector.

3.3 Research Implementations:

A comprehensive literature review has been conducted on energy management systems, ISO 50001 standards, and the energy efficiency landscape in both Finland and Germany. With this contextual understanding established, the following steps in research implementation have been identified:

- Conduct a thorough literature review on energy management systems, ISO 50001, and the energy efficiency of industries in Finland and Germany.
- Gather information from Finnish industries about their energy management practices and their reasons for not adopting ISO 50001.
- Collect additional data on energy consumption and efficiency in Finnish industries, as well as data from ISO on the number of ISO 50001-certified companies in Finland and Germany.
- Analyse the collected data to determine the reasons why Finnish industries have not widely adopted ISO 50001 and to compare the energy efficiency of Finnish industries with German industries.

3.4 Methodology:

To explain the methodology, it is essential to outline the approach taken to investigate ISO 50001 adoption within Finnish industries. A comprehensive understanding of the dynamics shaping energy management practices in this sector is sought. With this groundwork established, the specifics of data collection and analysis are outlined as follows:

Quantitative research methods will be used for collecting data from the questionnaire.

- Statistical analyses will be conducted on the collected data to determine trends and correlations.
- A comparative analysis will be conducted to compare the energy efficiency of Finnish industries with German industries.

- A mixed-methods approach will be used to combine the quantitative data from the questionnaire with the qualitative data from the literature review and interviews with industry experts to gain a more comprehensive understanding of the factors influencing ISO 50001 adoption in Finnish industries.

3.5 Data collection

To conduct this study the data has been collected from various sources to combine and do the statistical analysis. The mind map for collecting the data is presented in Figure 4.

Figure 4 Data collection mind map

3.5.1 European Manufacturing Survey 2022 (EMS) Questionnaire.

This questionnaire is the main source of the data which is used for this study. It includes 26 sections and multiple questions in each section which was distributed online to the Finnish industrial sector.

3.5.2 International Standards Organization (ISO) Database 1993-2022

The number of issued certificates per ISO standard and for different regions is available in the ISO database. This gives valuable data about Finland and Germany's certification history. For

this study, the data regarding ISO 9001, ISO 14001, and ISO 50001 is used to combine and verify the data collected from the EMS 2022 questionnaire

3.5.3 Finland National Statistical Institute and Germany Federal Statistical Office

To understand and estimate the penetration rate of each standard, some information regarding the number of active companies in each region is required. This data has been extracted from the official website of each region.

3.5.4 Data from literature

Some qualitative data, like the drivers and relations between standards for further discussion in the analysis part are required which is provided by a literature review which is discussed earlier in this study.

4 Results and discussion

For a better understanding of how to respond to the subject's questions, a mental framework has been outlined in this study. Within this overall framework, statistical and comparative studies are conducted between Finland, Germany, Europe, and the world. Initially, we will address the depiction of the current status of issued standard certifications in the mentioned regions. Subsequently, we will examine the trend and rate of reaching the current situation. To achieve this, we will make use of the data available in the International Standards Organization database. Furthermore, we will proceed to examine and study the data obtained from an EMS questionnaire, and the conformity of this data will be compared with the data of the International Standards Organization.

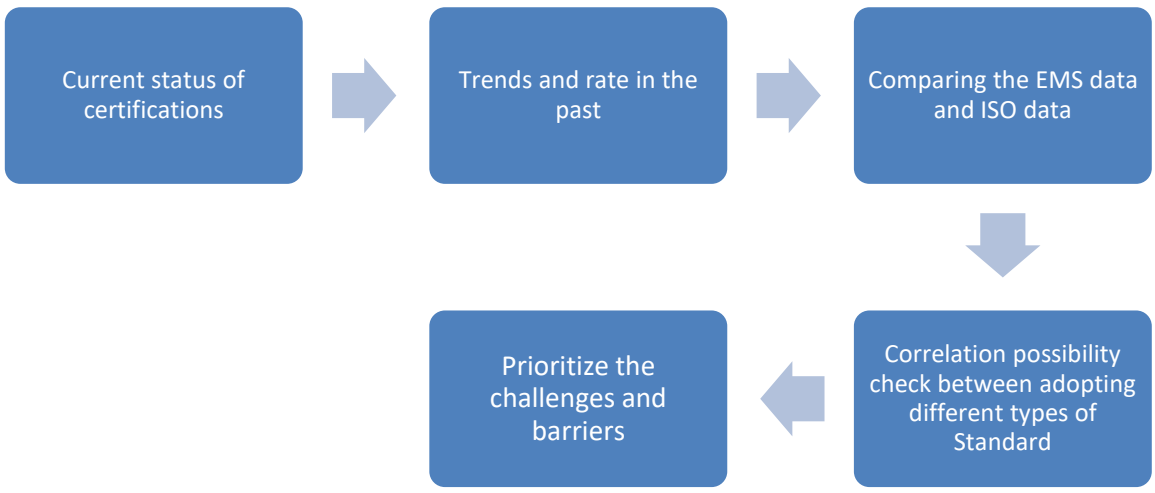
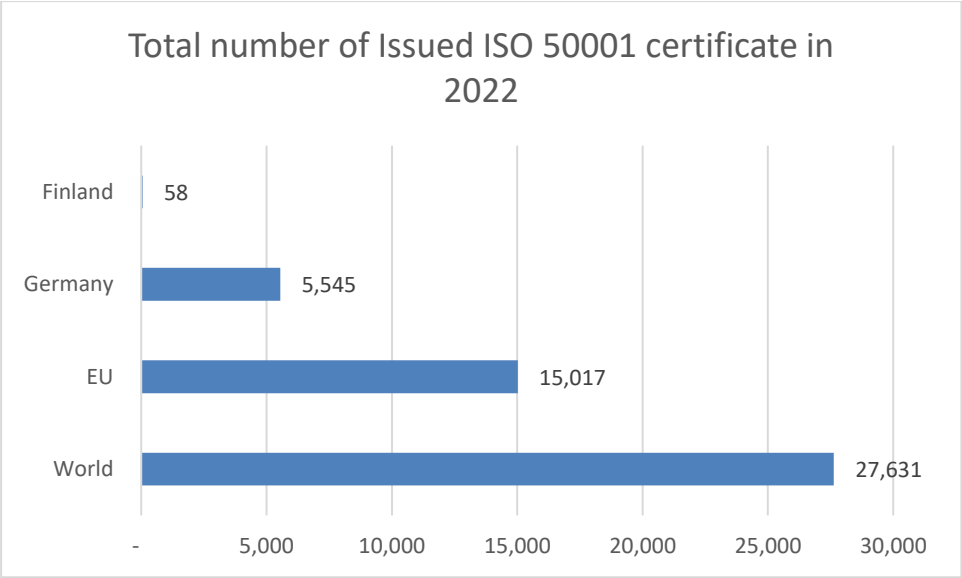


Figure 5 outlines and mind map of data analysis.

4.1 Latest certification status

4.1.1 ISO 50001 certifications status

As of February 2024, the latest available data from ISO certification belongs to 2022 which is available on the ISO official website. The number of issued ISO 50001 certificates reported by certified bodies who reply to the ISO survey is presented in Graph number 1.



Graph 1 Comparison total number of issued ISO 50001 certificates in 2022.

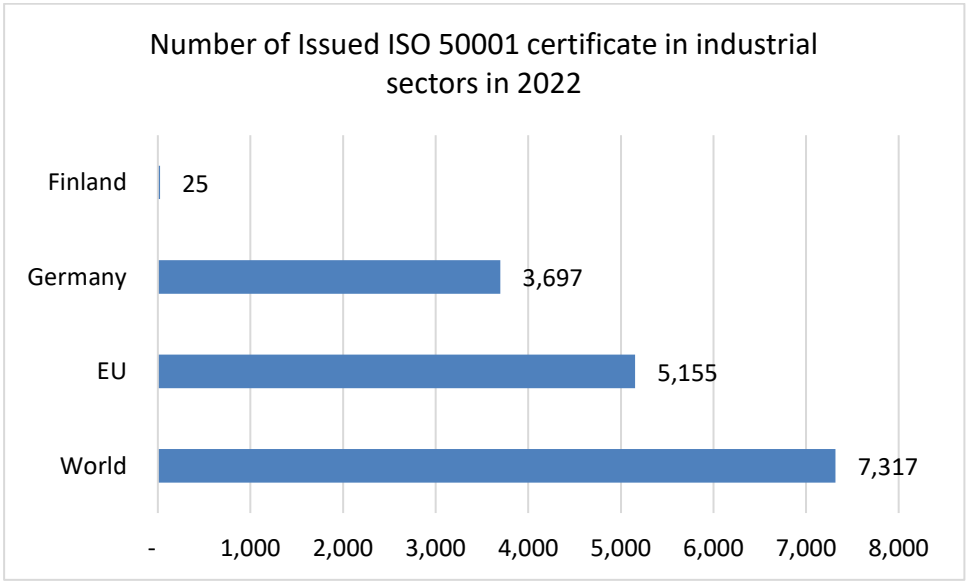
As depicted in Graph 1, the total count of ISO 50001:2011&2018 certificates in 2022 across all economic sectors is 58. Given the potential overlap and difficulty in distinguishing manufacturing and industrial sectors in certain databases, this study opts to classify the following industries specifically as manufacturing industries.

Table 4 Industry sectors that consider manufacturing or industrial in this study.

Row	*Industry sector*
1	Agriculture, Fishing and Forestry
2	Mining and quarrying
3	Food products, beverages, and tobacco
4	Textiles and textile products
5	Leather and leather products
6	Manufacture of wood and wood products
7	Pulp, paper, and paper products
8	Publishing companies
9	Printing companies
10	Manufacture of coke & refined petroleum products
11	Nuclear fuel
12	Chemicals, chemical products & fibers

Row	*Industry sector*
13	Pharmaceuticals
14	Rubber and plastic products
15	Non-metallic mineral products
16	Concrete, cement, lime, plaster, etc.
17	Basic metal & fabricated metal products
18	Machinery and equipment
19	Electrical and optical equipment
20	Shipbuilding
21	Aerospace
22	Other transport equipment
23	Manufacturing not elsewhere classified
24	Recycling
25	Electricity supply
26	Gas supply
27	Water supply

This data regarding the industrial sectors is presented in Graph 2.



Graph 2 Comparison number of issued ISO 50001 certificates in the industrial sector in 2022.

Graph 2 illustrates a correlation between the number of certificates issued in industrial sectors and the overall certificates issued in 2022. It is noteworthy that the ISO database includes certificates categorized under "unknown sectors," which we classify as non-industrial for this study. Furthermore, Table 4 provides an overview of the top 5 most certified industries in both Finland and Germany.

Table 5 compares between top 5 most certified industries in Finland and Germany

Number of issued ISO 50001certificates in 5 most certified industry			
Germany	Qty	Finland	Qty
Metal fabrication	735	Pulp and paper	13
Rubber and plastic	549	Electricity supply	5
Food and beverage	526	Food and beverage	2
Machinery and equipment	269	Fishing and forestry	1
Chemical products and fiber	257	Chemical products and fiber	1

Drawing insights from the presented data, it is evident that the majority of issued certificates in Finland are related to the pulp and paper sector and the electricity supply industry. In contrast, Germany stands out with the highest certification prevalence in the metal fabrication and food and beverage industries.

For a more comprehensive comparison, it would be beneficial to incorporate the total number of active registered companies in both countries. This normalization process would enhance the accuracy of the analysis, providing a more nuanced understanding of certification distribution across industries in Finland and Germany. According to Germany's Federal Statistical Office and Finland's National Statistical Institute, the total number of active companies and industries in 2022 in both countries is shown in Table 6 (Finland's National Statistical Institute, 2023; Germany Federal Statistical Office, 2023).

Table 6 Total number of active companies and industrial companies in Finland and Germany in 2022

Germany		Finland	
Active companies	Industrial companies	Active companies	Industrial companies
3,400,000	302,471	562,000	33,124

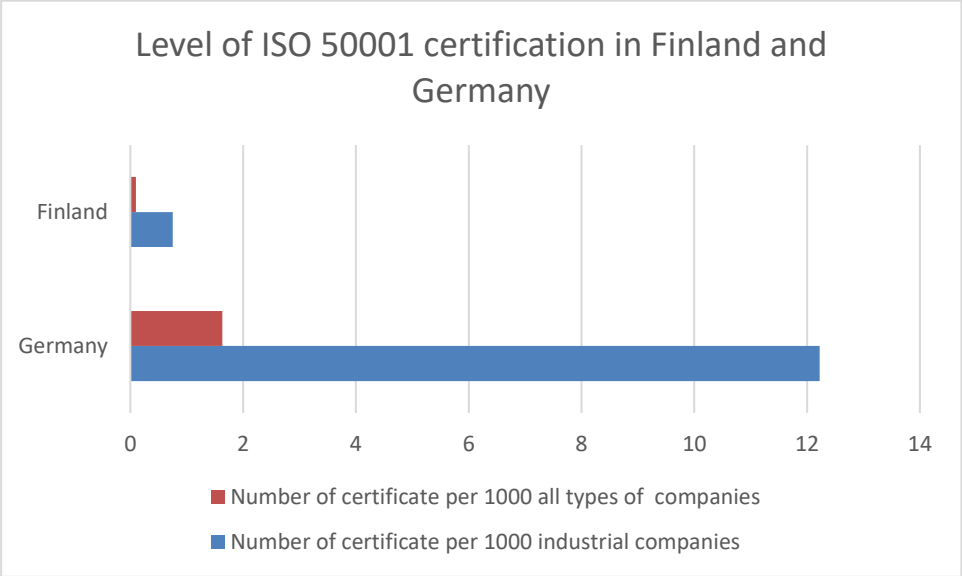
By normalization and introducing several issued certificates per 1000 industries, the following results are gained:

$$Number\ of\ issued\ ISO\ 50001\ certificate\ per\ 1000\ all\ companies = \frac{Number\ of\ issued\ certificate\ in\ all\ companies}{Total\ number\ of\ active\ companies} \times 1000$$

This value for Finland is 0.1 certificate per 1000 companies whereas Germany has 1.63 certified by ISO 50001 per 1000 companies. This value shows there is a meaningful gap between the level of certification in these two countries.

$$Number\ of\ issued\ ISO\ 50001\ certificate\ per\ 1000\ industrial\ companies = \frac{Number\ of\ issued\ certificate\ in\ Industrial\ companies}{Total\ number\ of\ active\ industrial\ companies} \times 1000$$

This value for Finland is 0.75 certificate per 1000 industrial companies whereas Germany has 12.22 certified by ISO 50001 per 1000 industrial companies. Graph 3 illustrates the difference in the adoption level between Finland and Germany.

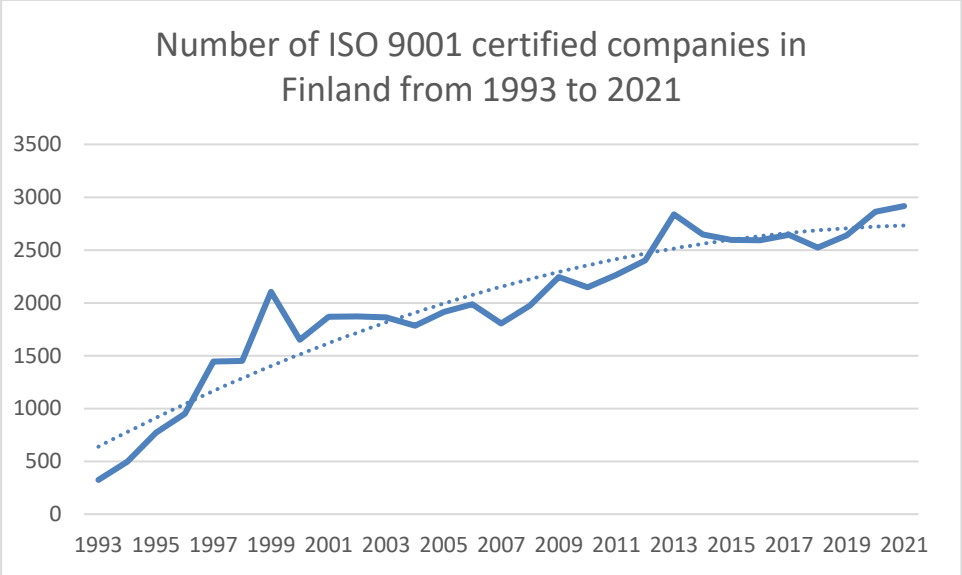


Graph 3: comparison chart for the level of ISO 50001 certification between Finland and Germany

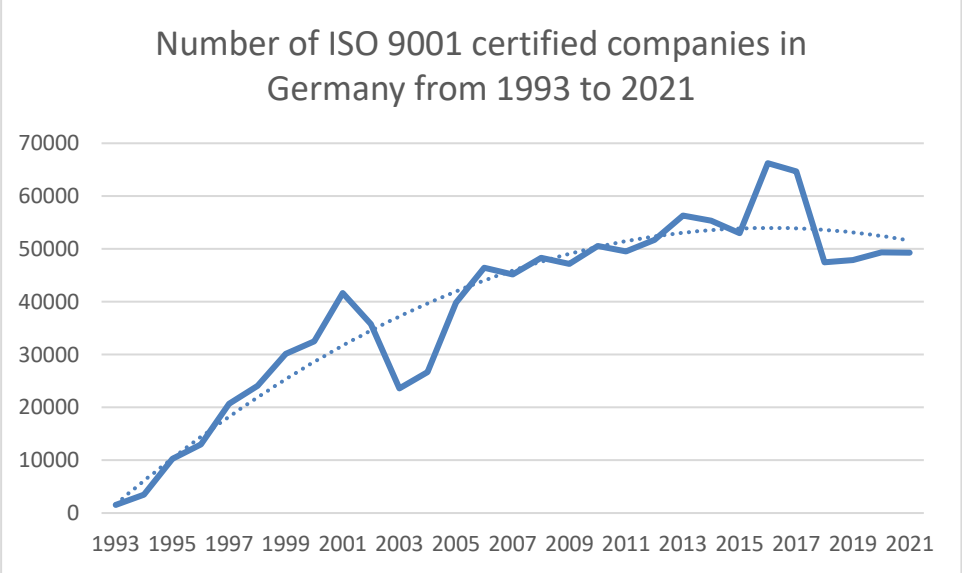
This value shows there is a meaningful difference between the level of certification in these two countries. However, it is also shown that the level of certification in the Industrial sectors is much higher in both countries.

4.1.2 ISO 9001 and 14001 Certification

As previously mentioned, J. Sousa Lira et al. identified a correlation between the adoption of ISO 50001 and the pre-existing standards ISO 9001 and ISO 14001. While ISO 50001 does not mandate the establishment of these standards as prerequisites, their presence can facilitate the implementation of ISO 50001(Sousa Lira et al., 2019). Notably, ISO 50001 was introduced in 2011, whereas ISO 14001 and ISO 9001 were introduced in 1996 and 1987, respectively. However, the certification data is only available from 1999 and 1993 respectively. Consequently, it is worthwhile to compare the current and history of the certification status of these two standards, then we can compare the growth rate of certification between standards. Graphs 4 and 5 represent the number of ISO 9001-certified companies from the first year of introduction to 2021 in Finland and Germany respectively.



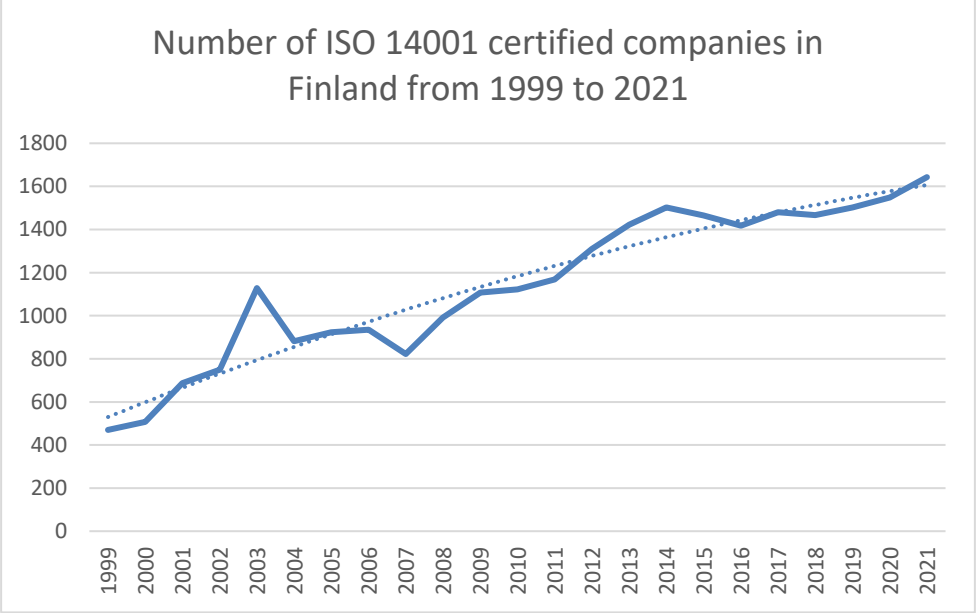
Graph 4 number of ISO 9001-certified companies through years in Finland



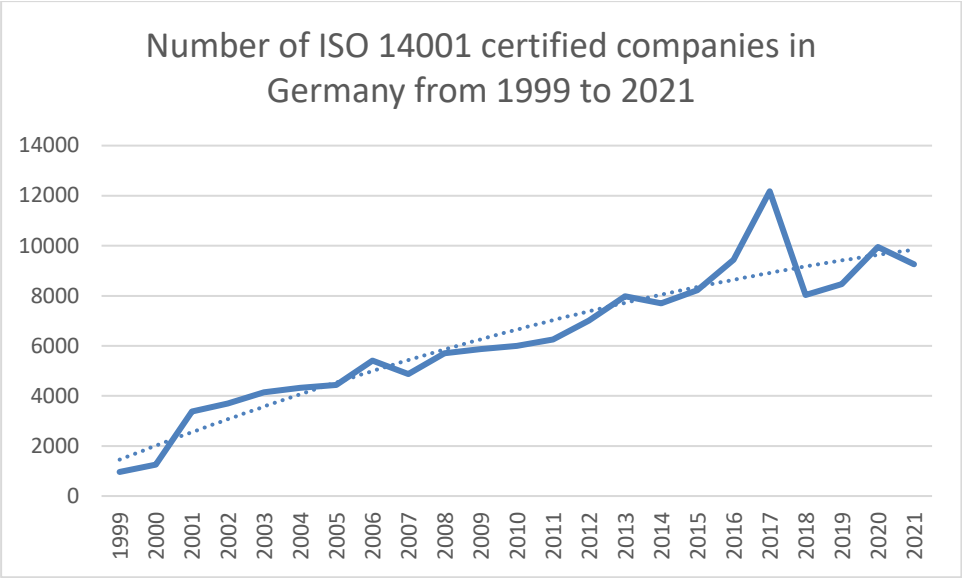
Graph 5 number of ISO 9001-certified companies through years in Germany

By comparing graphs 4 and 5, it can be seen that although both countries follow similar trends for implementation of ISO-9001, the number of ISO-9001-certified companies in Germany is much higher than in Finland. There was a decline in 2019 and 2020 which might be due to the COVID-19 pandemic.

In addition to ISO 9001, as mentioned earlier ISO 14001 which is an environmental management standard is also well-known and relevant to ISO-50001. Understanding the history and the certification growth rate in Finland and Germany can give a better image on the understanding of the adoption rate of ISO 50001.



Graph 6 number of ISO 14001-certified companies through years in Finland



Graph 7 number of ISO 14001-certified companies through years in Germany

From Graph 6 a steady growth in the number of ISO 14001-certified companies in Finland can be seen which reached close to 1800 certificates in 2021. On the other hand, Graph 7, a rapid increase in the number of certificates and reached approximately the peak point of 12000 certificates in Germany in 2017. Then a sharp decrease in the number of ISO 14001-certified happened and stabilized at 8000.

4.2 Comparison adoption rate of certification in the last 12 years:

To compare the adoption rate of ISO9001, ISO 14001, and ISO 50001, the period of 2011 to 2022 which is the common period in which all 3 standards exist has been selected. In Table 7 the penetration rate of all these standards in both countries is presented.

Table 7- adoption rate of ISO certificates in Finland and Germany from 2011 to 2022

Year	Finland (ISO50001)	Germany (ISO50001)	Finland (ISO 14001)	Germany (ISO 14001)	Finland (ISO9001)	Germany (ISO9001)
2011	0.000%	0.001%	0.208%	0.184%	0.403%	1.457%
2012	0.001%	0.033%	0.233%	0.206%	0.428%	1.521%
2013	0.002%	0.073%	0.253%	0.235%	0.505%	1.656%
2014	0.002%	0.100%	0.267%	0.227%	0.471%	1.628%
2015	0.005%	0.174%	0.261%	0.242%	0.462%	1.559%
2016	0.008%	0.265%	0.252%	0.278%	0.461%	1.948%
2017	0.007%	0.245%	0.263%	0.358%	0.470%	1.902%
2018	0.008%	0.184%	0.261%	0.236%	0.449%	1.397%
2019	0.004%	0.170%	0.267%	0.249%	0.470%	1.408%
2020	0.008%	0.189%	0.276%	0.293%	0.509%	1.451%
2021	0.009%	0.181%	0.292%	0.272%	0.519%	1.450%
2022	0.010%	0.148%	0.302%	0.387%	0.539%	1.380%

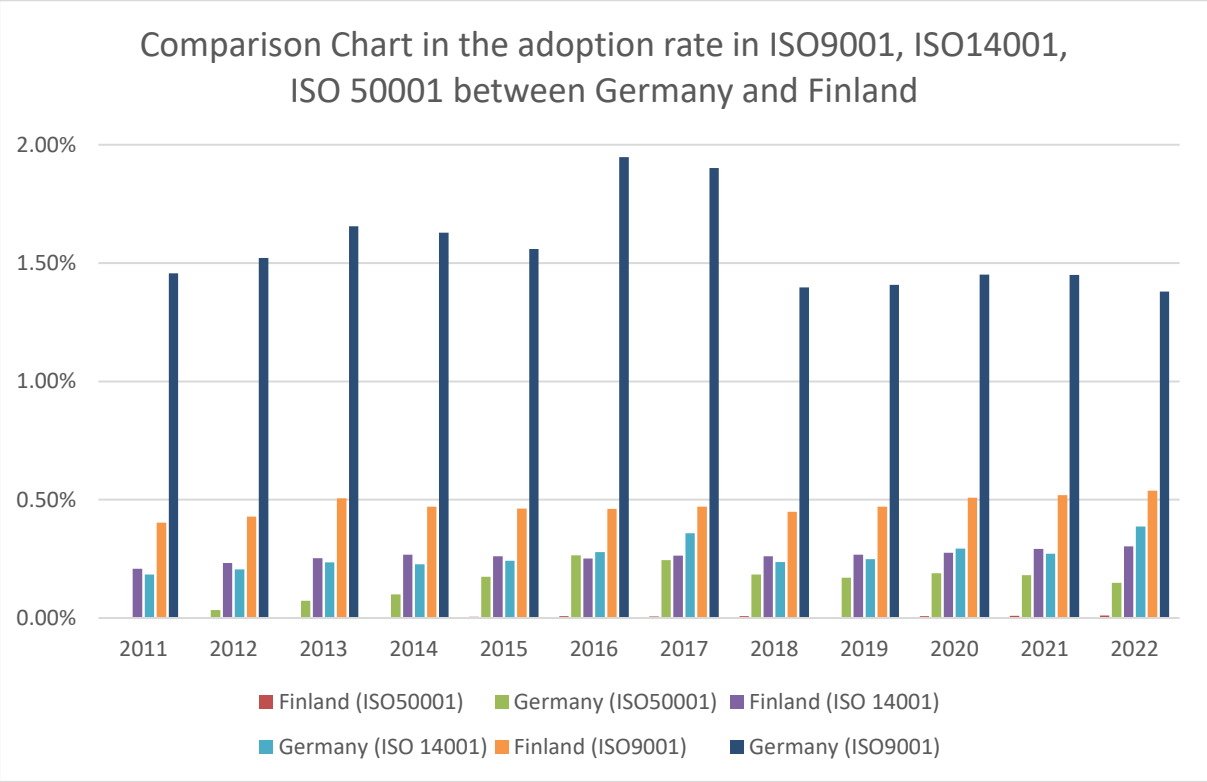


Figure 6-ISO 9001, ISO 14001, and ISO 50001 adoption rate comparison chart between Finland and Germany

From the comparison chart and data, the level of adoption of ISO 9001 and ISO 50001 is higher in Germany compared to Finland. However, the level of adoption of ISO 14001 is almost the same. In fact, from 2018 to 2021 Finland had a slightly higher adoption rate than Germany.

4.3 European Manufacturing Survey (EMS) 2022 Finland:

In 2022, the EMS group at Turku University surveyed to collect information from several Finnish industries and manufacturers to investigate the vital impact of innovation on sustainable growth. In response to this questionnaire, 123 responses were received. Sections of the questionnaire focused on the use of technologies to increase productivity, the implementation of production management systems, and their control. Specifically, questions were asked about the implementation of an energy management system and obtaining ISO 50001 certification. This section of the results is dedicated to analyzing the questionnaire's findings and comparing them with the relevant section.

4.3.1 Participants demographic

In this section, the demographic overview of the participants is illustrated. To have a better understanding of the Finnish manufacturing sector, the information about the number of employees and annual turnover in million Euros of these companies is presented below.

Table 8-Descriptive statistics of annual turnover in 2021

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
2021 Turnover	78	.4	339.0	26.555	52.6984
Valid N (listwise)	78				

Out of 123 responses, 78 answered the 2021 turnover which the results are presented in Table 8. The average annual turnover is around 26 million EUR in 2021

In Table 9, the descriptive statistics regarding the number of employees are presented. It is worth mentioning that out of 123 responses, 85 answered this question. From 85 valid responses, the mean is equal to 84 employees per company.

Table 9- Descriptive statistics of the number of employees in 2021

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Number of Employees	85	3	600	84.00	115.410
Valid N (listwise)	85				

The distribution of participants in 6 industry sectors is presented in Table 10. Machinery industry with 30 caseshas the highest frequency and followed by Technical and R&D services with 21 cases.

Table 10- distribution of iresponses in the type of industry sector

Statistics

Industry Sector

N	Valid	117
	Missing	0

Industry Sector

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Machinery	30	25.6	25.6	25.6
	Automotive	5	4.3	4.3	29.9
	Chemical	6	5.1	5.1	35.0
	Logistics	5	4.3	4.3	39.3
	Technical and R&D services	21	17.9	17.9	57.3
	Trade	6	5.1	5.1	62.4
	others	44	37.6	37.6	100.0
	Total	117	100.0	100.0	

The number of certified companies for ISO14001 and ISO50001 are represented in Table 11 and Table 12 respectively.

Table 11- Number of ISO 14001-certified companies

ISO14001 Certified

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	77	62.6	62.6	62.6
	Yes	46	37.4	37.4	100.0
	Total	123	100.0	100.0	

Table 12- Number of ISO 50001-certified companies

ISO50001 Certified

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	119	96.7	96.7	96.7
	Yes	4	3.3	3.3	100.0
	Total	123	100.0	100.0	

As is shown, 37.4% of respondents are certified for ISO 14001 whereas only 3.3% are certified for ISO 50001. This is an important factor that shows that the penetration rate of ISO 14001 is relatively high and proves the awareness of the importance of environmental concerns by industries.

In the second hypothesis, it is assumed that "The adoption of ISO 50001 is positively correlated with the establishment of energy management systems in the Finnish industrial sector". To test this hypothesis a Chi-Square test has been carried out and the P-value in the Chi-Square test is less than 0.05 so it can be concluded that there is a significant correlation between having an EnMS and being certified with ISO 50001. The results are presented in Table 13.

Table 13- Chi-Square Tests for testing the correlation between EnMS and ISO 50001 certification

Chi-Square Tests					
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.036[a]	1	.849		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.037	1	.846		
Fisher's Exact Test				1.000	.665
Linear-by-Linear Association	.036	1	.849		
N of Valid Cases	123				

Table 13 points out that the possibility of companies adopting ISO 50001 without having an established EnMS is low in Finland. While ISO 50001 is specifically focused on energy management systems, it's plausible that a company might adopt ISO 50001 for reasons other than having a fully implemented EnMS. For example, they might do so for marketing

purposes, to meet regulatory requirements, or to demonstrate environmental responsibility without fully integrating energy management practices into their operations.

In the EMS questionnaire, there is a question that asks about using any kind of energy-efficiency technology in the company. It is worth seeing if there is any connection or correlation between having an EnMS and using energy efficiency technologies. To evaluate this, a Pearson Bivariate method is being utilized and the results are presented in Table 14.

Table 14- Pearson Bivariate method for correlation between EnMS and Using energy efficiency technologies

Correlations

		Using Energy efficiency Technology to reduce energy usage	Have EnMS system software
Using Energy efficiency Technology to reduce energy usage	Pearson Correlation	1	.290**
	Sig. (2-tailed)		.001
	N	123	123
Have EnMS system software	Pearson Correlation	.290**	1
	Sig. (2-tailed)	.001	
	N	123	123

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

From Table 14, it can be concluded that there is a significant correlation between the establishment of an EnMS and Using energy efficiency technologies to reduce energy usage. This is also another sign that maybe the need for certification is not a main driver for the implementation of ISO 50001.

In hypothesis H3 it is assumed that “Lack of awareness and knowledge about ISO 50001 is a major reason for the low adoption of ISO 50001 in the Finnish industrial sector.” To evaluate and test this hypothesis due to the lack of direct questions about the awareness of existing ISO-50001, awareness of ISO 14001 is considered as a basis of the evaluation. ISO-14001 is well-known and well-adopted in both countries. A chi-square test has been conducted to check if there is an association between ISO 14001 and ISO 50001 certification. It is important, because if the level of Association between these two variables is significant, then it cannot be concluded that the difference between several certifications may be a result of awareness. The results of the test is presented in Table 15.

Table 15- Chi-Square test results about the correlation between ISO14001 and IS 50001 certification status

ISO14001 Certified * ISO50001 Certified Crosstabulation

Count

		ISO50001 Certified		
		No	Yes	Total
ISO14001 Certified	No	76	1	77
	Yes	43	3	46
Total		119	4	123

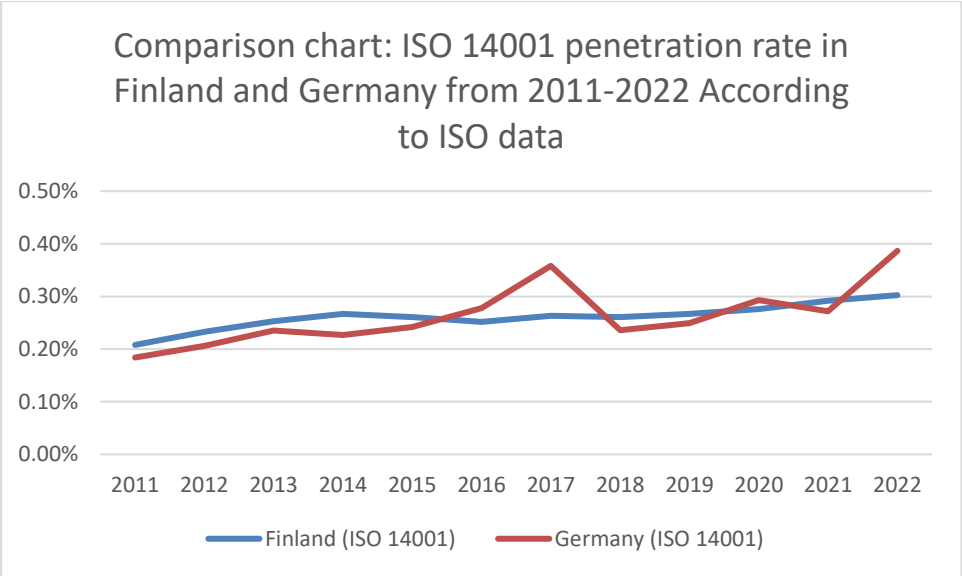
Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.497[a]	1	.114		
Continuity Correction[b]	1.113	1	.291		
Likelihood Ratio	2.421	1	.120		
Fisher's Exact Test				.147	.147
Linear-by-Linear Association	2.477	1	.116		
N of Valid Cases	123				

a. 2 cells (50.0%) have an expected count of less than 5. The minimum expected count is 1.50.

b. Computed only for a 2x2 table

Although due to the lack of enough data especially about the number of ISO-50001 certified companies, it could not be concluded that there is a relation between these two certificates, it is worth noting that The level of penetration rate for ISO-14001 in both countries follows almost the same trend whereas it was not the case for ISO-50001 which is shown in Graph 8.



Graph 8- ISO 14001 penetration rate in Finland and Germany from 2011-2022 According to ISO data

According to EMS 2022 results, 37.4% (see Table 12) of respondents are certified for ISO 14001 whereas only 3.3% (see Table 11) are certified for ISO 50001. This is an important factor that shows that the penetration rate of ISO 14001 is relatively high and proves the awareness of the importance of environmental concerns by industries, whereas the awareness of ISO 50001 in Finnish industry may be lower.

In the last hypothesis H4, it is assumed that "Providing financial incentives and promoting awareness about the benefits of ISO 50001 can promote adoption of ISO 50001 in the Finnish industrial sector". Due to existing direct questions in the questionnaire in this regard, it is decided to check the annual turnover instead. So, it means companies who earn more money, are more likely to implement the ISO 50001 and ISO 14001. To test this a Binary regression logistic model has been created to check if this model can predict the implementation by the amount of turnover good enough. For this test, ISO 14001 and ISO 50001 certification status are considered dependent variables, and annual turnover is the independent variable. The results of the model are presented in Table 16.

Table 16-Binary logistic regression model to predict the ISO 50001 implementation by knowing the annual turnover

Omnibus Tests of Model Coefficients

	Chi-square	df	Sig.

Step 1	Step	3.685	1	.055
	Block	3.685	1	.055
	Model	3.685	1	.055

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	31.590[a]	.030	.118

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Classification Table[a]

			Predicted		
			ISO50001 Certified		Percentage
	Observed		No	Yes	Correct
Step 1	ISO50001 Certified	No	119	0	100.0
		Yes	4	0	.0
	Overall Percentage				96.7

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	2021 Turnover	.010	.005	4.194	1	.041	1.010
	Constant	-3.516	.570	38.045	1	.000	.030

a. Variable(s) entered on step 1: 2021 Turnover.

Due to the low number of certified companies by ISO 50001 in the EMS survey, the Binary logistic regression model for ISO 50001 certification does not appear to be statistically significant, and the predictor variable (2021 Turnover) does not significantly predict certification status. Additionally, the model fails to effectively predict cases of ISO 50001 certification, as it does not correctly classify any cases in the "Yes" category. However it is worth mentioning that the average turnover of ISO 50001-certified companies is 48 million EUR whereas non-certified companies have 16 million EUR, so this needs to be investigated further in future studies.

The same model has been used to predict ISO 14001 implementation and the results are presented in Table 17.

Table 17- Binary logistic regression model to predict the ISO 14001 implementation by knowing the annual turnover

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	.623	1	.430
	Block	.623	1	.430
	Model	.623	1	.430

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	161.993[a]	.005	.007

a. Estimation terminated at iteration number 3 because parameter estimates changed by less than .001.

Classification Table[a]

			Predicted		
			ISO14001 Certified		Percentage
	Observed		No	Yes	Correct
Step 1	ISO14001 Certified	No	76	1	98.7
		Yes	46	0	.0
	Overall Percentage				61.8

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	2021 Turnover	.002	.003	.621	1	.431	1.002
	Constant	-.480	.191	6.303	1	.012	.619

a. Variable(s) entered on step 1: 2021 Turnover.

Based on the Table 17 results, while the overall model is statistically significant, the specific coefficient for the 2021 Turnover variable is not statistically significant at the 0.05 level. Therefore, there is not enough evidence to conclude that companies with higher annual turnover are more likely to get certified by ISO 14001, at least based on this analysis.

5 Conclusion

This thesis explores the adoption of ISO 50001 within the Finnish industrial sector, comparing it with Germany to understand the implementation gap. The challenges and motivations behind this gap are examined, providing insights into the level of adoption and factors influencing it.

In the exploration of ISO 50001 adoption within the Finnish industrial sector compared with Germany, several significant findings have been revealed:

The first hypothesis posited that the utilization of ISO 50001 in the German industrial sector is higher compared to the Finnish industrial sector. The results showed a significant disparity in adoption rates between Germany and Finland, with Germany exhibiting a penetration rate over 1600% higher than Finland. Additionally, while Germany experienced a steady increase in adoption over time, Finland did not follow a similar trend. The outbreak of the pandemic in 2019 further exacerbated this discrepancy.

In the second hypothesis, a strong correlation between the establishment of energy management systems (EnMS) and ISO 50001 certification in the Finnish industrial sector was observed. The analysis confirmed this hypothesis, indicating a strong relationship between the presence of EnMS and ISO 50001 certification in Finland. However, intriguingly, ISO 50001 adoption was observed in some companies without fully implementing EnMS, suggesting alternative motivations for certification beyond energy management practices.

The third hypothesis aimed to determine if a lack of awareness and knowledge about ISO 50001 is a major reason for the low adoption of ISO 50001 in the Finnish industrial sector. For this purpose, ISO 14001 which is well well-known and well-accepted standard in both countries is selected to do the comparison. However, the comparison of ISO 14001 and ISO 50001 certification rates between the two countries revealed divergent trends. While ISO 14001 adoption remained consistent across both countries, the adoption of ISO 50001 varied significantly. The notably higher adoption rate of ISO 14001 in Finland suggests a greater awareness of environmental concerns compared to ISO 50001.

Lastly, the fourth hypothesis suggested that providing financial incentives and promoting awareness about the benefits of ISO 50001 would promote its adoption in the Finnish industrial sector. While the logistic regression model did not yield statistically significant results, indicating that factors such as annual turnover did not effectively predict certification

status, certified companies demonstrated a higher average turnover compared to non-certified counterparts. This suggests potential financial incentives influencing certification decisions, warranting further exploration in future studies.

The significant disparity in adoption rates between Germany and Finland underscores the importance of addressing barriers to adoption within the Finnish industrial sector. Despite the potential for substantial cost savings and environmental benefits associated with ISO 50001 implementation, challenges such as limited financial resources, weak leadership commitment, and data management difficulties persist. These barriers inhibit organizations from realizing the full potential of ISO 50001 in improving energy efficiency and sustainability.

Furthermore, the comparison with previous energy management standards, particularly EN 16001:2010, highlights the advancements and appeal of ISO 50001. Its integration into existing management systems and alignment with other ISO standards position ISO 50001 as a valuable tool for organizations seeking to enhance their energy management practices.

The literature review provides additional insights into the drivers and motivations behind ISO 50001 implementation. From cost savings to environmental responsibility, organizations are motivated by a variety of factors to pursue ISO 50001 certification. However, the persistence of implementation challenges, such as weak leadership commitment and cultural barriers, necessitates targeted policies and initiatives to support adoption efforts.

Moreover, the tangible benefits of ISO 50001 implementation, as evidenced by case studies demonstrating significant reductions in energy consumption and greenhouse gas emissions, underscore its potential to drive positive environmental and financial outcomes. By addressing barriers and leveraging facilitators such as top management support and energy awareness culture, organizations can maximize the benefits of ISO 50001 certification.

5.1 Recommendations for further studies

For further studies, several avenues emerge from the findings and insights gathered:

Expanded Sample Size: Expanding the sample size to include a larger and more diverse set of companies across different industries in both Finland and Germany could provide a more comprehensive understanding of ISO 50001 adoption dynamics. Additionally, exploring the adoption patterns in other European countries could offer valuable comparative insights.

Exploration of Direct Incentives: Further investigation into the impact of direct incentives, such as free certification opportunities, on organizations' willingness to adopt ISO 50001 would be beneficial. Understanding the role of financial incentives in overcoming implementation barriers and encouraging adoption could inform policy interventions aimed at promoting ISO 50001 certification.

Comparison with Other Energy Management Standards: Including other energy management standards, particularly those prevalent in the US, for further comparison could enhance our understanding of ISO 50001's unique features and benefits. Comparative analysis with standards such as ANSI/MSE 2000:2008 or ANSI/MSE 50021:2010 could provide insights into the relative effectiveness and applicability of different energy management frameworks.

Longitudinal Study on Energy Performance: Conducting a longitudinal study to collect post-certification energy-saving data from ISO 50001-certified companies in Finland and comparing it with non-certified companies' energy performance over time would offer valuable insights into the long-term effectiveness of ISO 50001 implementation. Analyzing trends in energy consumption and cost savings post-certification could provide evidence of the sustained impact of ISO 50001 on energy management practices.

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