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Assessment and management of climate change mitigation policies in various sectors of EU countries

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Abstract: The paper analyses problems of climate change mitigation policy management in various sectors of EU countries. It assesses the effectiveness of climate change mitigation measures in GHG emission reduction based on a systematic literature review and analysis of various policy documents and reports. A comparative analysis of climate change mitigation policies between various sectors and various EU countries was performed to define the best practices and develop recommendations to enhance climate change mitigation policies and measures in the worst-performing EU sectors and countries.

Keywords: climate change mitigation, policies and measures, management, EU countries, comparative analysis, policy recommendations.

JEL: Q58; P18; Q13

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Introduction

Climate change mitigation policies are vital for the EU to address environmental, economic, and social challenges. They aim to reduce greenhouse gas emissions (GHG), protect biodiversity, and foster a transition to a green economy that creates jobs and ensures energy security (Liang, 2023). Proactive policies help avoid the high costs of climate inaction, improve public health, and safeguard vulnerable regions around the world. (Du et al., 2024). As a global leader, the EU sets an example through ambitious targets and international cooperation while enhancing resilience to climate impacts. These policies align with ethical commitments and legal obligations and aim to achieve a sustainable, climate-neutral future for current and future generations.

Scholars review a broad range of literature that looks into the possibilities, the issues, and the approaches surrounding climate change mitigation policies adopted in the European Union (Zahfira, 2024; Dupont, 2023; Beaufils, Pires, 2023; Kettner, Kletzan-Slamanig, 2020; Liobikiene, Buzogany, 2019).

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A broad understanding of the EU's approach to combating climate change includes a prominent focus on afforestation and the consequent increase in carbon sinks. According to Caporaso (2024), European forests make appreciable contributions to increased cloud cover and carbon storage, which forms part of the EU's climate target strategy and is part of the European Green Deal (Caporaso, 2024). Besides the realm of forestry, the energy sector remains an essential component of the climate change mitigation strategy of the EU. The Emission Trading System was created in 2005, and it is one of the measures of the EU to mitigate the emissions of GHG. The issuance of the ETS has been extensively researched, and specific studies have been able to find that some GHG emission reductions have been made, although there are still difficulties in ensuring that the emission trading scheme is robust and can meet different economic conditions (Stepanyan et al., 2023). Kettner and Kletzan-Slamanig elaborate on how energy efficiency and renewable energy policies drive climate policy processes. However, they also observed that the degree of integration was partial, causing ineffectiveness in climate change mitigation (Kettner & Kletzan-Slamanig, 2020).

Agriculture is another sector where climate change mitigation policies are becoming more important. The European Union has a sizable GHG agriculture sector while also having the potential to combat GHG emissions through different sustainable practices. The use of nitrogen fertilizers, as illustrated by the farm-to-fork strategy of the European Green Deal, should also be reduced alongside more promotion of organic farming and other methods to increase climate change mitigation (Tutak et al., 2021; Luyckx, Reins, 2022). Foldal (2024) demonstrates that policies allow for reduced soil nitrous oxide emissions while maintaining defined levels of crop yield, but the agricultural land competitiveness dilemma exists, and the balance between environmental and socioeconomic factors is complicated.

Big cities are essential when it comes to the fight against global warming because they are the ones who typically take action on climate change issues. Reckien et al. analyzed local climate plans submitted by 885 European cities and found that there are distinct differences between how cities are going to deal with climate issues (Reckien et al., 2018). The paper fully demonstrates the scope of local governance participation in climate change action and describes the synergies and trade-offs that exist between both mitigation and adaptation strategies in cities (Reckien et al., 2018). Urban planning as a factor in reducing climate change is also confirmed by Jēkabsone et al. (2021), who analyze the shift in the intention of municipalities from Sustainable Energy Action Plans (SEAP) to Sustainable Energy and Climate Action Plans (SECAP), suggesting that integrated paths to climate change governance are increasingly needed (Jēkabsone et al., 2021).

International collaboration and governance arrangements also shape the policies of the European Union on climate change. Shyrokykh et al. (2023) shed light on the nature of EU climate cooperation with its neighborhood countries, arguing that mitigation and adaptation are two sides of the same coin. This approach operates at a regional level, in which it tackles all the interaction linkages that are inherent in

climate change, since mitigation in most cases calls for assistance from outside the borders of the nation. The authors (Olaru and Banacu, 2018) also emphasize the need to incorporate climate change into policies such as economic development and security, which should be followed to achieve climate change targets while other targets are also being pursued.

In particular industries, such as manufacturing and energy, trade unions and labor organizations are beginning to communicate with climate change policies. Studies discuss the European response to climate policies, specifically emphasizing the trade unions' actions towards the policy (Thomas & Doerflinger, 2020). When workers' rights are integrated into the politics of climate, this should guarantee that climate policy is equitable. These issues cannot be neglected when considering how effective climate policies will be set, as they help all parties involved in the climate policies to avoid conflicts that could stem from implementing the policy (Sario, Sacchi, 2023).

Another notable theme in the literature is the intersection of green financing techniques with climate change policy measures. Scholars elaborate on the green finance priorities of the EU, insisting that there is a need to restructure financial flows as a response to climate change (Arriba-Sellier, 2021). This green finance transition is essential in providing funding for climate objectives and creating opportunities for new technology developments that would aid in combating climate change (Caravella et al., 2021). The intersection of climate policy and finance is an important area of study as it may have considerable implications for climate change mitigation measures.

The analysis of climate change policy management in different sectors across EU member states indicates that advancements and gaps are interrelated. It is crucial to harmonize the climate change mitigation measures taken in key sectors such as forestry, energy, agriculture, industry, and city planning to meet the climate goals of the EU. Additionally, the need for international, state, and municipal collaborations, social dialogue, and green financing indicates the complexity of climate change governance. The policies and efforts that the EU implements to combat climate change will require further studies and policymaking initiatives to improve their effectiveness, equity, and sustainability.

The paper aims to address this gap and provides a review and critical assessment of climate change mitigation policies and their management challenges in various sectors of the economy of EU member states.

The paper is structured as follows: section 1 presents a literature review, Section 2 introduces methods and data, Section 3 discusses results, and Section 4 concludes.

1. Literature review

The climate change mitigation policies demand multi-faceted strategies due to their multi-sectoral approaches and differing levels of implementation and effectiveness (Wang et al., 2023). This literature review offers updated insights on the status of

climate change mitigation policies management in the EU regarding significant sectors, including agriculture, energy, industry, etc.

Agriculture is a priority sector for climate change mitigation in the EU, but this sector has always been somewhat behind other industries in making great strides toward a decrease in GHG emissions. The studies critically analyzed the EU's Common Agricultural Policy (CAP) due to the slow integration of climate objectives (Spiegel et al., 2021; Barbieri, 2024; Schmidt, 2019). For example, the energy sphere has set up some reasonable objectives for climate change, while the focus and resources for the agriculture sector have not been allocated to the same extent (Spiegel et al., 2021; Schmidt, 2019). Such inconsistencies raise some questions regarding the overall adequacy of the strategy designed for climate change mitigation in the EU and suggest that a much more rational, synergized approach combining the agricultural policies and climate objectives should be sought (Zafeiriou et al., 2018; Schmidt, 2019). According to Barbieri (2024), it is necessary to focus on synergy and trade-off shifts to climate change adaptation and mitigation in agriculture, making agriculture one of the most essential sectors regarding GHG emissions reduction, as climate change adaptation. Barbieri (2024) posits that scaling climate-smart agricultural practices can improve climate resilience while reducing GHG emissions. Public views on climate change mitigation are critical as evidence that the general population considers it the duty of government institutions to act on climate change. Such a belief could also affect agricultural policies, considering that only public support is necessary to successfully implement and maintain climate change measures (Luyckx & Reins, 2022).

Furthermore, investigating the challenges and opportunities of climate change policies cannot ignore the effect of the carbon pricing mechanism, of which the EU Emission Trading System (EU ETS) is an example (Bruninx, Ovaere, 2022). Stepanyan et al. (2023) highlight that the EU ETS, which accounts for about 40% of the EU GHG emissions, has significantly fostered GHG emission decreases in the energy sector; however, implementation in the agricultural industry could be positive. Overlapping agricultural practices with ETS would expand their usefulness in climate change mitigation (Verschuuren, 2018). Modest carbon prices in agriculture can be treated as an obstacle to implementing effective climate mitigation practices because there have been virtually no policy incentives in the agriculture sector, especially in livestock, a major GHG emissions contributor in agriculture.

Apart from the agricultural sector, the land use, land-use change, and forestry (LULUCF) sector brings forth opportunities and challenges in climate change mitigation (Kazanavičiūtė & Dagiliūtė, 2023). This sector, which involves GHG emissions and removals, is politically sensitive. Thus, caution must be observed when determining policy frameworks to ensure that these do not achingly affect the overall mitigation aims (Kazanavičiūtė & Dagiliūtė, 2023). In addition, the policies addressing LULUCF will be determined by the integration between national policies and those at the level of the EU, which a study by Vartolomei (2018) shows to be problematic due to the conflicting priorities of member states.

The energy industry, especially in renewable energy utilization, has demonstrated considerable input to the EU's climate change mitigation efforts. This is because the EU has set clear targets for the broader adoption of renewable energy sources necessary for achieving long-term climate goals (Stepanyan et al., 2023; Luderer et al., 2019). Notably, this is a very challenging issue as it requires investment in infrastructure and technology and public acceptance of new energy technologies (Luderer et al., 2019). This energy and climate change mitigation nexus requires addressing these multifaceted issues more comprehensively by involving new technologies, regulatory structures, and the participation of key players (Luderer et al., 2019).

Energy-intensive industries can provide significant GHG emission reductions due to the implementation of new energy-efficient technologies (Fragkos et al., 2021) and switching to use of renewables for energy generation (Singh et al., 2023).

Studies have emphasized the lack of contribution of the transport and tourism industry in climate change mitigation (Löffler et al., 2022; Valente, Medeiros, 2022). The transport sector of EU countries has been highlighted as one of the areas that needs a great deal of reforms in order to achieve the climate goals. According to Miskinis et al. (2022), the present trends of GHG emissions within the transport industry are worrying. New policies are urgently required to facilitate the uptake of green transport innovations. The authors posit that in the absence of substantial changes in transportation policies, meeting climate obligations may be challenging for many EU countries (Stepanyan et al., 2023). In addition, regional approaches to climate issues, such as mitigation and adaptation, are likely to bolster the resilience of the transport system and free up infrastructure. It is vital to include climate projections in state plans because they can assist in determining and managing the potential impacts of climate change on transportation systems (Jēkabsone et al., 2021).

The studies stressed that large climate governance requires the inclusion of climate objectives on all levels of decision-making, for example, local, country, and EU levels (Homeyer et al., 2021; Standarti et al., 2023). The creation of networks like the Mayors' Covenant has encouraged the sharing of best practices between cities and regions, which has resulted in tremendous success in combating the climate change challenge as a whole. However, the policy disintegration and the different levels of Member States' capabilities to implement climate regimes present problems in forming a coherent and efficient climate action across the EU (Homeyer et al., 2021).

Assessing mitigation policies in the context of the specific objectives and goals of the EU, it can be noticed that mutual interests and diversification of the stakeholders that hold differing positions and attitudes are essential determinants for climate change mitigation policy success (Fujiwara et al., 2019). Olaru and Bănacu (2018) discuss the role of national policies in the EU in facilitating member efforts to reduce GHG emissions. Studies by Amman & Boussat (2022) and Rekien & Landauer

(2018) argue that various national policies should be aligned with EU directives for properly coordinated climate actions in the regions.
Climate policies rely on public support through engagement and education (Nayna Schwerdtle et al., 2023). Miltiadou et al. (2021) emphasize the need to be accompanied by effective communication tools to strengthen the public's grasp of the impact climate change has, as well as the importance of participation in curbing further escalation of the issue. Bolstering the people's will to work for the better ensures a suitable environment for implementing climate policies (Miltiadou et al., 2021).
The literature reviews how EU countries have implemented various climate change mitigation policies consisting of either complementarity or synergies. There have been some advancements in implementing these measures at the EU level. However, several gaps exist, especially in agriculture and land use areas. EU member countries need to formulate policies that broaden their perspectives beyond a single sector, as this would open even more gaps in climate and energy policies, which conflict with each other.

2. Data and methods

The study examines the available literature on how policies are implemented at the EU level. The analysis is based on a comparison of climate change mitigation policies within and across sectors and EU countries. The effectiveness of climate change mitigation policies was assessed, demonstrating the best practices and those that require improvement.
The research is based on secondary data sources, namely EU policy reports and official documents that can be accessed from data available at Odyssee-Mure (2024).
A Sectoral Assessment was performed by classifying policies and measures into the following sectors: Transport, Industry, Households, and Services.
The different policy instruments were grouped into the regulatory measures, financial instruments, market-based strategies, as well as training and information dissemination.
Quantitative analysis of GHG emission reduction potential was performed for countries based on available data on energy saving identified for specific policy tools in Odyssee-Mure (2024).
The study estimated the GHG emissions reduction potential in each EU country based on total energy savings planned for 2030, based on implemented climate change mitigation measures. To achieve emissions reduction targets, a standardized GHG emission factor (56.1 kg CO_2/GJ as per IPCC (2006) guidelines) was deployed.
The policy heterogeneity across the EU member states and how that influences energy savings and GHG emissions reduction outcomes was evaluated.
Overall, methods applied include methods of literature review, comparative assessment, and quantitative evaluation of the effects of climate change mitigation measures in various economic sectors of EU member states.

3. Assessment of climate change mitigation measures in various sectors

Climate change mitigation policies vary across EU Member States, each implementing measures to mitigate climate change across different sectors. In Table 1, climate change mitigation policies were grouped according to categories and sectors by providing EU countries that have implemented these policies and measures based on information available in Odyssee-Mure (2024).

Table 1. Climate change mitigation policies and measures in various sectors

Category	Type of Policy/Measure	Sector	EU Member States
Regulation	Mandatory Information - Labelling	Transport	AT, BE, CY, DK, FI, FR, DE, EL, HU, IE, IT, LV, LT, LU, NL, RO, SI, ES, SE
	Energy Management - Energy Audits	Industry	AT, BE, BG, DK, FR, DE, EL, HU, IT, LV, PT, SK, SI, ES, SE
	Labels - Mandatory Labelling of Electrical Appliances	Households	BE,BG, CY, FR, DE, EL, HU, IT, LV, LT, NL, PT, SK, SI, ES
	Energy Management - Energy Audits	Services	BE, BG, DK, FR, EL, IT, LV, RO, ES
Financial	Subsidies for Clean and Efficient Vehicles	Transport	AT, BE, BG, HR, CY, CZ, FR, DE, EL, HU, IE, IT, LV, LT, LU, MT, NL, PL, PT, RO, SI, ES
	Tax Reduction for Clean and Efficient Vehicles		AT, BE, CY, DK, FI, FR, DE, EL, IE, LV
	Accelerated Depreciation	Industry	FR, IT, LU, NL
	Subsidies for Efficient/Renewable Heating Technologies		AT, BE, BG, HR, CY, CZ, DK, FI, DE, EL, HU, IE, IT, LV, LT, NL, PL, RO, SK, SI, ES, SE
	Subsidies for Efficient/Renewable Heating Technologies	Households	AT, BE, BG, CY, CZ, DK, DE, EL, HU, IT, LV, LT, LU, MT, NL, PL, RO, SI, ES
	Tax Credit		BE, FI, FR, DE, IT, LV, NL, PL, SE
	Subsidies for Investments in Efficient/Renewable Heating Technologies	Services	BE, BG, CY, CZ, DK, EE, FI, FR, DE, EL, IE, IT, LV, LT, NL, PL, SK, SI, ES
	Accelerated Depreciation		NL, PT
Information/ Training	Information on Energy Efficient Driving Behaviour	Transport	AT, BE, BG, CZ, DK, EE, FI, EL, LT, LV, NL, SI, ES, SE
	Smart Metering and Informative Billing	Households	AT, BE, BG, FI, FR, DE, EL, LV, NL, ES

Category	Type of Policy/Measure	Sector	EU Member States
Market based instruments	Emission Trading	Industry	AT, CZ, FI, FR, DE, IT, LU, RO, SK
	Energy Saving Obligation	Services	DE, EL, IE, RO
Others	Car Sharing	Transport	AT, FR, DE, EL, IT, LV

Source: the author's contribution based on Odyssee-Mure (2024)

Table 1 provides a systematic summary of policies and measures aimed at enhancing energy efficiency in four economic sectors: Transport, Industry, Households, and Services. These policies can be classified into five groups, which include: Regulations, Financial, information/training, market-based instruments, and others. Analysing the distribution of policies and measures across the sectors, one can notice that in the transport sector, policies are mainly aimed at regulatory (labelling), subsidizing (subsidies, tax), and information campaign (efficiency-driving education) activities. In the industry sector, policies and measures are focused on energy management (audits), subsidizing (subsidies, tax), and market-based instruments (emission trading). In the household sector, policies and measures cover appliance labelling, subsidies for efficient heating devices, information/training on intelligent metering and billing. The focus of the service sector ranges from energy audits, subsidising energy technology for heating, to energy-saving obligations.

Regulatory Measures such as labelling and energy audits are done in all four economic sectors in the majority of EU member states, but serve different purposes and have varying approaches of implementation. Transport and Households focus on labelling for energy efficiency, while Industry and Service rely on the audits to assess and improve overall energy utilization. Therefore, the regulatory measures are one of the most important means of enhancing energy efficiency in different sectors.

Financial measures play a very important role as a stimulus for energy saving. The transport sector has been receiving economic assistance in the form of subsidies for the purchase of clean vehicles and reduced taxes for energy-efficient transport. Industry and Households have much greater access to renewable heating technologies, for instance, in the form of subsidies and tax rebates. The services sector also enjoys subsidization for the purchase of energy-efficient heating devices. As all these incentives in all sectors is an indication that economic support is a key determinant of energy efficiency.

Market-based measures were implemented only in the industry and service sectors. Emission trading schemes are in place in Austria, the Czech Republic, Finland, France, Germany, Italy, Luxembourg, Romania, and Slovakia for the industry sector. Some countries, for example Germany, Greece, Ireland, and Romania, have energy-saving targets for businesses, and these should make them consume less energy. These remaining market measures are soft, too few, but important for those sectors where emissions have to be controlled directly.

Information and Teaching Activities in transport include Campaigns seeking to promote energy-efficient driving habits are common. In households, initiatives like smart meters and informative billing are employed to assist users in managing energy consumption and costs. This implies that these behavioral policies are critical in complementing the financial and regulatory policies.

Some EU member countries (Austria, France, Germany, Greece, Italy, Latvia) have implemented car-sharing programs aimed at promoting shared transportation and alleviating traffic congestion. This might not be as popular as other methods, but they still aid in decreasing emissions and augmenting energy efficiency within the transport system.

EU countries have implemented various climate change mitigation policies and measures across sectors. Austria, Belgium, France, Germany, and Italy lead in regulatory, financial, and market-based measures. Spain and the Netherlands actively support renewable energy and sustainable transport. Other countries, such as Finland, Denmark, and Greece, also contribute to efficiency through subsidies, tax incentives, and information programs

The policies and measures for climate change mitigation work hand in hand since they are based on some kind of administrative action, funding, training, and even the use of some market mechanisms. These measures are not always explicit policies. The last three are the most important in all sectors. It shows that these economies are trying to encourage energy efficiency by the means of economic support.

Most of these are used for compliance purposes, especially among regulatory measures such as labelling and auditing. Policies of information and training help to fill the gap between energy-saving measures and practices. It can be noted that the most promising set of policies would include a combination of financial support, regulations, and promotional and educational programs targeting the public.

Energy efficiency policies vary across EU Member States, each implementing measures to improve sustainability across different sectors.

The following Table 2 consolidates the various climate change mitigation policies and measures, and their impacts across sectors and countries. GHG emission reduction ($MtCO_2e$) was assessed based on total energy savings, multiplied by 56.1 kg CO_2/GJ is the standard GHG emission factor for energy savings in the EU based on (IPCC 2006 guidelines).

Table 2. Energy saving in EU countries and GHG emission reduction potential due to climate change mitigation measures in various sectors by 2030

EU Country	Type of P olicy/Measure	Sector	Total Energy Savings Due to Policies in 2030 (PJ)	GHG Emission Reduction Potential (MtCO2e)
Austria	Energy Performance of Buildings Directive (EPBD), Energy Consultants of the Federal Government	Buildings, Information/ Training	1.08	60.59
Belgium	Recast Ecodesign Directive, Compulsory Energy Audits for Large Buildings	Mandatory Standards, Mandatory Information	1.90	106.59
Bulgaria	Modernization of Municipal Outdoor Lighting, Educational Infrastructure, Renewable Energy Program	Financial	0.48	26.93

EU Country	Type of P olicy/Measure	Sector	Total Energy Savings Due to Policies in 2030 (PJ)	GHG Emission Reduction Potential (MtCO2e)
Croatia	Energy Renovation of Public Buildings, Energy Management System	Financial, Information/T raining	1.89	106.03
Cyprus	Energy Efficient Street Lighting, Installation of PV in Government Buildings	Financial, General Programme	0.50	28.05
Czechia	Modernisation Fund, Operational Programme Environment	Financial	5.15	289.82
Denmark	Energy Efficiency in Governmental Institutions, EPBD Building Regulations	General Programme, Mandatory Standards	1.22	68.44
Estonia	Renovation of Social Care Homes	Financial	0.02	1.12
Finland	Information Service on Energy Efficiency Financing, Regulations for Nearly-Zero Energy Building	Information/T raining, Mandatory Standards	0.51	28.61
France	Building Code of 2012 (RT 2012), Éco Energie Tertiaire (EET)	Mandatory Standards, Mandatory Information	63.48	3562.43
Germany	National Top Runner Initiative (NTRI), Climate-Neutral Federal Administration	Mandatory Information, Mandatory Standards	70.78	3972.76
Greece	ELECTRA Programme for Public Buildings	Market-Based Instruments	0.54	30.29
Hungary	Energy Efficient Public Building Management	Information/T raining	0.09	5.05
Ireland	SEAI Pathfinder Programme	Information/T raining	0.08	4.49
Italy	Programme for Energy Renovation of Public Buildings, Subsidies for Energy Efficiency	Financial	1.19	66.76
Latvia	Energy Audits & Energy Management Systems	Mandatory Information	0.07	3.92
Lithuania	EU Structural Funds for Digitalization	Financial	0.07	1.68
Luxembourg	Energy Renovation Obligation for Buildings	Mandatory Standards	0.12	6.73
Malta	Energy Efficiency Measures for Public Buildings	General Programme	0.02	1.12
Netherlands	Investment Subsidy for Sustainable Energy	Financial	0.27	15.14

EU Country	Type of P olicy/Measure	Sector	Total Energy Savings Due to Policies in 2030 (PJ)	GHG Emission Reduction Potential (MtCO2e)
Poland	Energy-Efficient Building Construction	Financial	15.76	885.94
Portugal	EU Energy Labelling Framework	Mandatory Standards	0.27	15.14
Romania	Long-Term Renovation Strategy	Financial	34.75	1950.68
Slovakia	Renovation of Public Historic Buildings	Financial	0.06	3.36
Slovenia	Project Office for Energy Renovation	Others	0.02	1.12
Spain	Energy Audits & Management Systems	Mandatory Information	1.26	70.69
Sweden	Not Available	N/D	N/D	N/D

Source: the author's contribution based on Odyssee-Mure (2024)

As one can see from Table 2, Germany (3,972.76 $MtCO_2e$) and France (3,562.43 $MtCO_2e$) are leading with the highest planned GHG emission reduction potentials due to large-scale building regulation policies and financial incentives. Romania (1,950.68 $MtCO_2e$) and Poland (885.94 $MtCO_2e$) follow, benefiting from long-term renovation strategies and energy-efficient construction initiatives. Moderate GHG emission reductions are planned by Czechia (289.82 $MtCO_2e$), Belgium (106.59 $MtCO_2e$), Croatia (106.03 $MtCO_2e$), Austria (60.59 $MtCO_2e$), and Spain (70.69 $MtCO_2e$). These countries implement building efficiency measures, modernization funds, and regulatory frameworks that contribute to significant GHG emission reductions.

Low GHG reductions (<100 $MtCO_2e$) were planned by Denmark (68.44 $MtCO_2e$), Italy (66.76 $MtCO_2e$), Portugal (15.14 $MtCO_2e$), and the Netherlands (15.14 $MtCO_2e$) contribute through sector-specific subsidies and efficiency frameworks.

Small-scale GHG reductions is seen in Estonia (1.12 $MtCO_2e$), Malta (1.12 $MtCO_2e$), Lithuania (1.68 $MtCO_2e$), and Latvia (3.92 $MtCO_2e$) due to the small size of the economy.

Countries with strong financial and regulatory frameworks (Germany, France, Poland, Romania) contribute the largest reductions in GHG emissions. Mid-range countries implement effective but smaller-scale policies, leading to moderate reductions. Smaller economies (Malta, Estonia, Lithuania) achieve lower reductions due to fewer large-scale energy efficiency measures. Assessing these GHG emission reduction potentials per capita also shows that Germany, France, Poland, and Romania are the top countries in GHG emission reduction potential due to climate change mitigation policies.

The sector that achieved the highest energy savings and GHG emission reduction in the study is the Buildings Sector (including Households, Commercial, and Public Buildings). Therefore, the Buildings Sector is the most impactful sector for energy

savings and GHG reductions, followed by the Industrial and Transport sectors. Investments in energy-efficient buildings and renovations contribute significantly to the EU's climate goals. Most effective policies in the building sector are regulatory Policies, including the Energy Performance of Buildings Directive (EPBD) and national building codes, mandatory audits, and energy efficiency standards for large buildings. Financial Incentives in the form of subsidies for energy renovation and insulation, and Tax reductions and financial support for energy-efficient appliances are also effective measures to achieve high GHG reduction potential.

4. Results discussions

The data and information obtained in this study are in line with other studies analysing climate change mitigation policies and their achievements in the EU. Germany plays a significant role in EU climate change mitigation efforts. Country has made great progress in the deployment of renewable sources of energy due to its marking policy known as Energiewende (Wang et al., 2023). Due of such a policy framework, there has been a consistent rise in the proportion of renewables of the total energy in Germany, and that has been linked to a significant GHG emissions decrease (Wang et al., 2023). However, there are barriers, especially in transportation, where GHG emissions have not decreased as fast as in other sectors (Löffler et al., 2022). The national strategy should include fast penetration of electric vehicles, as this fosters lowering GHG emission rates, thus the necessity for joint policies between various sectors (Löffler et al., 2022). The country implements strict regulatory measures, including mandatory labelling for electrical appliances and energy audits for industries and services. Financial incentives such as subsidies for clean vehicles, renewable heating technologies, and tax credits encourage businesses and households to adopt sustainable energy solutions. Germany also actively participates in market-based instruments like emission trading and energy-saving obligations. These efforts make Germany one of the leading nations in driving energy efficiency and reducing carbon emissions across the EU.
On the other hand, France's climate change policies have continually focused on nuclear energy as a clean energy source. As the French government has always depended on nuclear energy for their electricity needs, the country has always maintained a low level of GHG emissions when compared to other developed nations (Wang et al., 2023). Nevertheless, such dependence on nuclear energy raises issues with regards to energy security, nuclear energy public acceptance and the future of nuclear energy technology (Wang et al., 2023). Policies have now attempted to change the energy mix by increasing investments in renewable energy technologies, but the speed of the transition has been slower than predicted as according to the French National Low-Carbon Strategy, the country aims to achieve carbon neutrality by the year 2050 (Wang et al., 2023). France has established a strong framework for climate change mitigation through regulatory and financial policies. The country enforces mandatory labelling of electrical appliances and promotes energy audits

across industries and services. Financial mechanisms such as tax credits, subsidies for clean vehicles, and incentives for renewable heating technologies help drive energy efficiency at all levels. France is also a key participant in emission trading and has implemented accelerated depreciation policies to encourage investments in sustainable infrastructure.

The Dutch experience also offers an interesting perspective as the formulation of climate change policies was driven by the environmental geography of the country, including threats of flooding and the impact of global warming. Different schemes have been developed to deal with the risks including the construction of sustainable facilities and improvement of flood management systems (Wang et al., 2023). The Netherlands is at the forefront of climate change mitigation policies, implementing a combination of regulatory, financial, and market-based measures. The country actively supports emission trading and offers accelerated depreciation benefits for industries investing in sustainable technologies. Financial incentives, including subsidies for renewable heating technologies and tax credits, encourage both businesses and households to adopt energy-efficient solutions. Additionally, the Netherlands promotes energy-efficient driving behavior and smart metering programs to enhance energy conservation efforts. These initiatives contribute to the country's strong commitment to reducing carbon emissions and fostering a sustainable energy future.

Other EU Member States also have extensive energy efficiency policies. Austria has a strong focus on transport and industry regulations, including mandatory labelling and energy audits. Belgium provides extensive financial incentives, such as subsidies and tax credits, to encourage efficient energy use. Denmark implements a wide range of market-based instruments, including energy-saving obligations and emission trading. Finland prioritizes smart metering and informative billing to improve household energy efficiency. Spain has significant policies supporting clean transport, renewable energy subsidies, and emissions trading, reinforcing its commitment to sustainability. These nations, along with others, are making remarkable strides in improving energy efficiency and increasing use of renewables.

Some EU Member States have implemented relatively fewer climate change mitigation policies. Countries such as Malta, Cyprus, and Romania have limited regulatory measures and financial incentives in place compared to old EU Member States. Their efforts mainly focus on select areas such as transport or household efficiency improvements. Additionally, Lithuania and Latvia have introduced some initiatives but still lack comprehensive, large-scale programs. These nations face challenges such as limited funding and smaller industrial sectors, which impact the extent of their energy efficiency and other climate change mitigation measures. According to Miskinis et al (2021), there is a large potential for deployment of RES technologies in heating and cooling applications in the Baltic States region, but the transport needs to be transformed completely to be able to meet climate change mitigation targets. However, for the rapid development of renewable energy the massive transformational investments are necessary (Stepanyan et al, 2023).

5. Conclusions

EU Member States implement various climate change mitigation measures across sectors. Countries like Germany, France, and Poland lead in energy savings with strong financial and regulatory measures. Other nations, such as Austria, Belgium, and the Netherlands, focus on mandatory standards and financial incentives to drive efficiency. Some countries, including Malta and Estonia, have relatively smaller-scale policies due to economic and infrastructural limitations.

Countries like Germany, France, and Poland can lead in energy savings with strong financial and regulatory measures, also resulting in significant GHG emission reductions. Other nations, such as Austria, Belgium, and the Netherlands, focus on mandatory standards and financial incentives to drive efficiency. Some countries, including Malta and Estonia, have relatively smaller energy-saving and GHG emission reduction potentials due to the small size of their economy, etc.

The analysis reveals differences in the efficacy of climate mitigation policies across EU sectors. Buildings in the household and commercial sectors provide for most energy savings and GHG emission reductions, while transport still poses an issue. Stronger and bigger economies like Germany, France, and Poland can take advantage of powerful regulation and financing of GHG emission reduction initiatives, while weaker ones cannot implement the all range of policies

The main policy recommendations are to ensure policy alignment between sectors for maximum impact. Subsidies and Renovation efficiency standards should be increased for building renovations. Market-based approaches for carbon pricing should be enhanced in industry and services. Reforms in the transport sector should be accelerated by the promotion of electric vehicles and stricter CO_2 standards.

Limitations and Future Research. The approach taken involves secondary data, and there are several sectors with policy impact assessment that are not homogeneous. Future studies are necessary for the assessment of climate change mitigation policies impacts by conducting an assessment based on primary data for all EU countries.

Conflict of Interest Statement

The author does not have a conflict of interest.

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That is not the case.

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