Motivational schemes for conscious energy users

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Executive Summary

The completion of Task 6.4 within the D^2EPC project, titled "Development of Motivational Schemes for Conscious Energy Users" in the building sector represents a collaborative effort by the project consortium members to devise innovative motivational schemes for fostering energy-conscious behaviour. This endeavour entailed a comprehensive and systematic approach, strategically designed to collect, analyze, and utilize data essential for the creation of motivational schemes that encompass both rewards for energy efficiency and penalties for non-compliance.

The methodology employed throughout the process was characterized by its meticulous structure and its alignment with existing industry practices. It commenced with an in-depth examination of prevailing energy efficiency policies and schemes across Member States, facilitating the documentation and comprehension of current initiatives. This foundational phase established the basis upon which novel motivational schemes were crafted, aiming to not only harmonize with existing practices but also to address gaps and inefficiencies.

The analysis of existing schemes involved a thorough assessment focused on identifying commonalities and disparities, thus enabling the strategic anticipation and resolution of implementation challenges. The objective was to rectify shortcomings and introduce refined concepts to enhance the efficacy of proposed motivational schemes. Primary and secondary data collection methods were employed, including questionnaires and interviews, resulting in an expansive dataset that underpinned subsequent analyses.

The subsequent phase encompassed a rigorous and systematic analysis of collected data, revealing patterns, correlations, and divergences across policies and schemes. International theories and pricing systems that effectively incentivized carbon emission reduction on a global scale were integrated, enriching the knowledge repository that guided the motivational scheme development. Pilot studies were conducted to validate scheme viability and effectiveness, offering insights for refinement and optimization.

In conclusion, Task 6.4 exemplified a structured methodology executed by the D^2EPC consortium members, culminating in the development of motivational schemes informed by international best practices and rooted in an extensive data analysis process. These schemes are poised to revolutionize energy-conscious behaviour within the building sector, addressing gaps in existing paradigms and paving the way for improved energy efficiency practices.

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List of Acronyms and Abbreviations

Term	Description
BREEAM	BRE Environmental Assessment Method
CEE	Certificat d'économie d'énergie
CEN	European Committee for Standardization
CEA	Cyprus Electricity Authority
D.	Deliverable
EPC	Energy Performance Certificate
EPD	Environmental Product Declaration
EXE	Energy Saving
ETS	Emission Trading Scheme
EU	European Union
HVAC	Heating, Ventilation, and Air Conditioning
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCIA	Life Cycle Inventory Assessment
LEED	Leadership in Energy and Environmental Design
MS	Member State
NRRP	National Recovery and Sustainability Plan
PCR	Product category rules
RES	Renewable Energy Sources
RRF	Recovery and Resilience Fund
SRI	Smart Readiness Indicators
T.	Task
VALERI	Valuation of Energy-Related Investments
WP.	Work Package

1 Introduction

1.1 Work package and Task description

Task 6.4 *Development of motivational schemes for conscious energy users in the building sector* is part of Work Package 6 (WP6), where the main goal is to investigate policy-related implications for the enforcement of the next generation EPC schemes. WP6 aims at delivering practical knowledge that will eventually be integrated into national and European energy legislative frameworks.

T6.4 will examine, draft, and deliver a comprehensive scheme based on the Emission Trading Scheme (ETS), which will quantify and define the types of awards and penalties. The integration of the updates reference values into calculation processes, the redefinition procedure for building class energy, the methodology based on which the awards and penalties will be monetized, and the types of implementing the proposed penalties or awards will be explored as part of T6.4 as well as D6.4.

1.2 Interaction with Other Tasks and Deliverables

Due to the dynamic character of the field, Task 6.4 will interact with T6.2 particularly for Deliverable D6.6 concerning the second version of the recommendation report on the integration of NG EPC in national/regional certification schemes.

2 Methodology

For the successful completion of T. 6.4 “Development of motivational schemes for conscious energy users in the building sector”, the collaborative efforts of the D^2EPC project consortium members methodically devised and executed a comprehensive and systematic approach. This methodological framework was meticulously designed to ensure the comprehensive collection, thorough analysis, and subsequent utilization of data pertinent to the creation of motivational schemes, encompassing both incentivizing rewards and deterrent penalties. These schemes, in turn, formed the bedrock for the conceptualization of a robust evaluation methodology tailored for conscientious energy users within the building sector.

A preliminary phase of the methodology involved an exhaustive examination of prevailing policies and schemes relating to conscientious energy consumption across member states. This preliminary inquiry facilitated the documentation of existing initiatives, thereby enabling a thorough comprehension of the prevailing landscape of energy-efficient practices and policies. This stage of the methodology, rooted in the analysis of pre-existing schemes, was identified as pivotal, serving as the foundational cornerstone upon which the novel motivational schemes could be innovatively constructed. This approach aimed not only to harmonize with existing industry practices but also to potentially build upon or augment retired schemes.

The analysis of these extent schemes encompassed a comprehensive assessment with a dual focus on identifying commonalities and disparities. Through this assessment, any potential challenges that arose during the implementation phase were strategically addressed. The overarching objective was to identify gaps and inefficiencies within the existing paradigms, thereby setting the stage for the formulation of robust policies that would be recommended for adoption. The innovative essence of the D^2EPC project lay in its capacity to not only rectify prevailing shortcomings but also to introduce novel and refined concepts, consequently enhancing the efficacy of the motivational schemes proposed.

A combination of primary and secondary data acquisition strategies were collected via a variety of experimental and collection methods to document all existing incentives and penalty schemes in EU MSs that address the energy efficiency of buildings. Secondary data garnered through desk research undertaken by the task's consortium members was complemented by primary data acquired through a multifaceted approach. This approach encompassed the administration of questionnaires as well as the conduct of in-depth interviews with industry stakeholders and domain experts across diverse member states. This comprehensive data collection strategy culminated in an expansive dataset that formed the foundation for subsequent analyses.

Subsequent to the data acquisition phase, a rigorous and systematic analysis was conducted, aiming to distil and uncover patterns, correlations, and divergences across the policies and schemes implemented by individual MSs. This analytical endeavour constituted a pivotal juncture wherein insights were extracted, laying the groundwork for informed decision-making in the formulation of motivational schemes.

Furthermore, an exploration into international theories and pricing systems that have demonstrated effectiveness in incentivizing carbon emission reduction on a global scale was seamlessly integrated into the methodology. This proactive approach, driven by a quest for enhanced comprehension and insight, proved instrumental in enriching the knowledge repository underpinning motivational schemes' development. By drawing inspiration from successful models that had effectively induced change within polluting industries, the D^2EPC project harnessed these principles as cornerstones for its motivational schemes.

A critical validation phase was embarked upon the scrupulous finalization of the motivational schemes. Pilot studies were thoughtfully conducted to ascertain the real-world viability and effectiveness of the

devised schemes. These pilot studies provided a practical platform to assess the seamless implementation of the motivational schemes, shedding light on their potential impact and identifying areas for refinement.

In conclusion, the methodology employed within Task 6.4 "Development of Motivational Schemes for Conscious Energy Users in the Building Sector" epitomized a meticulously structured approach executed by the collaborative endeavours of the D^2EPC consortium members. It facilitated an expansive data gathering and analytical process that informed the creation of motivational schemes rooted in the augmentation of existing paradigms and guided by international best practices. The culmination of this rigorous process was the generation of motivational schemes poised to revolutionize energy-conscious behaviour within the building sector. **Table 1** representation offers a concise overview of each step within the methodology for the development of motivational schemes for conscious energy users in the building sector.

Table 1: Methodology for data collection and data analysis

N/A	Methodological Steps	Description
1	Preliminary Examination of Existing Schemes	▪ Review and document current energy efficiency programs and policies across MSs ▪ Identify commonalities and differences among existing schemes ▪ Address issues encountered during scheme implementation
2	Data Collection	▪ Secondary data acquisition through desk research by consortium members ▪ Primary data acquisition through targeted e-questionnaires, communication with competent bodies, and interviews with stakeholders and experts in MSs ▪ Formulation of an expansive dataset
3	Data Analysis	▪ Rigorous analysis of collected data to identify patterns, correlations, and discrepancies among policies and schemes ▪ Insights extraction to inform the formulation of motivational schemes
4	Best Practices	▪ Exploration of successful global theories and pricing systems incentivizing carbon emission reduction ▪ Assimilation of principles from these models as foundational elements for the motivational schemes
5	Synthesis of the proposed methodology	▪ Innovatively design motivational schemes based on analyzed data and international best practices ▪ Address identified gaps and shortcomings in existing schemes ▪ Definition of possible compliance and non-compliance tools ▪ Integrate new and improved ideas ▪ D^2EPC methodology for compliance of building users
6	Pilot Studies	▪ Validation of devised motivational schemes through pilot studies: ➢ Pilot site – FRC main building, Cyprus ➢ Pilot site – Smart House, CERTH, Greece ▪ Assessment of real-world implementation and effectiveness ▪ Identification of areas for refinement and optimization

3 General insights into the types of existing initiatives

3.1 Government Initiatives

In recent years, governments worldwide have been increasingly recognizing the significance of sustainable energy practices in addressing environmental concerns and enhancing energy security. Within the context of the building sector, a significant contributor to energy consumption and greenhouse gas emissions, various government initiatives have been formulated to promote energy efficiency and encourage conscious energy use [1]. This discourse delves into the landscape of government initiatives aimed at motivating energy-conscious behaviours among users in the MS building sector, shedding light on their objectives, strategies, and potential impact [2].

The primary objective of government initiatives targeting energy efficiency in the building sector is to mitigate the environmental impact of energy consumption while concurrently reducing energy costs for individuals and businesses. Given the climate changes, where cooling and heating demands are substantial, governments have to recognize the critical role energy-efficient practices play in curbing energy expenditure and minimizing carbon emissions. These initiatives are founded on the principle of fostering behavioural change among building occupants, thereby contributing to a more sustainable energy landscape.

One of the prevalent strategies that could be employed is the implementation of incentive-based programs. These initiatives offer financial incentives, such as subsidies, tax incentives, and grants, to encourage the adoption of energy-efficient technologies and practices. Notably, subsidies for solar panel installations and tax deductions for energy-efficient renovations exemplify the government's commitment to incentivizing sustainable actions. These initiatives seek to alleviate financial barriers and stimulate wider adoption by offsetting the initial costs associated with energy-efficient upgrades.

Another pivotal aspect of government efforts involves raising awareness and enhancing the understanding of energy-efficient behaviours among building occupants [3]. The government strives to empower citizens with the knowledge and tools necessary to make informed energy consumption decisions through comprehensive energy awareness campaigns, workshops, and educational seminars. By fostering a culture of energy consciousness, these campaigns aim to elicit behavioural changes that translate into reduced energy consumption.

Legislation forms a cornerstone of governmental action to drive energy efficiency. Governments have implemented stringent building codes that mandate energy-efficient design and construction practices for new buildings. These codes encompass aspects such as insulation, lighting, and heating, ensuring that newly constructed buildings adhere to high energy performance standards. Such regulatory frameworks exert a transformative influence on the building sector by embedding energy efficiency considerations into the core of architectural and construction practices.

Government initiatives in MS embrace collaboration with diverse stakeholders, including businesses, communities, and research institutions. Public-private partnerships are leveraged to expedite the implementation of energy-efficient technologies and practices. By engaging various actors, initiatives benefit from collective expertise, resources, and a shared commitment to sustainability, fostering a holistic approach toward achieving energy conservation goals.

While government initiatives demonstrate considerable potential, challenges such as public awareness gaps, funding limitations, and the need for sustained behavioural change remain pertinent. Overcoming these challenges necessitates continuous evaluation, adaptation, and innovative strategies.

In conclusion, government initiatives geared towards motivating conscious energy use within the building sector reflect a multi-faceted approach encompassing incentives, awareness campaigns, legislation, and stakeholder collaboration. By championing energy efficiency, these initiatives align with broader sustainability agendas and pave the way for a greener and more energy-conscious future.

3.2 Educational Campaigns

The EU MSs have embarked on a collective journey to mitigate the environmental impacts of energy consumption within the building sector. Recognizing the pivotal role of public awareness and education, numerous MSs have implemented educational campaigns as a key strategy to promote energy consciousness and sustainable behaviours. This discourse delves into the significance of educational campaigns in the context of energy efficiency within the building sector across EU MSs, exploring their objectives, methodologies, and potential contributions.

Educational campaigns within EU MSs target transforming individuals' energy consumption behaviours through knowledge dissemination and cultivating a sustainability-oriented mindset. The overarching objective is to empower citizens with information about energy-efficient practices, inspiring them to adopt conscious energy behaviours in their homes and workplaces [4]. By fostering a sense of collective responsibility, these campaigns contribute to the reduction of energy consumption, greenhouse gas emissions, and overall environmental impact.

Educational campaigns employ a multi-faceted approach to engage diverse audiences and maximize the reach of their messaging. Workshops, seminars, public lectures, and online webinars serve as interactive platforms for imparting information about energy-efficient technologies, behavioural changes, and the benefits of sustainable practices. These initiatives leverage a combination of visual aids, real-world case studies, and interactive demonstrations to enhance comprehension and encourage active participation.

Effective educational campaigns often harness insights from behavioural psychology to influence energy consumption habits. Principles such as social norms, positive reinforcement, and feedback mechanisms are strategically integrated to elicit desired behavioural changes. By highlighting the actions of peers who have adopted energy-efficient practices, campaigns tap into the power of social influence, compelling individuals to conform to sustainable norms.

Educational campaigns exhibit a keen focus on tailoring their content to address the diverse needs and motivations of their target audiences. Customized messaging takes into account demographic variables, socio-economic contexts, and cultural nuances that influence energy consumption patterns. This personalized approach increases the relatability of the campaign's messaging, fostering a deeper connection and greater resonance with the recipients.

Cross-sector collaboration and partnership amplify the impact of educational campaigns. Governments, non-governmental organizations, educational institutions, and private entities converge to share resources, expertise, and outreach networks. Synergy among these stakeholders enhances the campaign's effectiveness by expanding its reach and facilitating the implementation of hands-on activities and experiential learning opportunities.

The effectiveness of educational campaigns is often gauged through metrics such as increased public awareness, changes in energy consumption behaviours, and participation rates in related activities. Monitoring and evaluation mechanisms facilitate data-driven decision-making, allowing for the adjustment of campaign strategies and content to maximize impact.

As EU MSs progress toward their energy efficiency and sustainability goals, the role of educational campaigns remains pivotal. Embracing technological advancements and innovative communication

platforms, such as social media and virtual reality, holds promise for enhancing the efficacy of campaigns and engaging tech-savvy audiences.

In conclusion, educational campaigns represent a cornerstone of EU MSs' endeavours to cultivate energy consciousness and sustainable behaviours within the building sector. By disseminating knowledge, fostering behavioural change, and promoting collaborative efforts, these campaigns empower citizens to become active contributors to a greener and more energy-efficient future for the entire EU.

3.3 Smart Metering Programs

In pursuing sustainable energy practices, EU MSs have turned to innovative solutions to curb energy consumption and promote efficiency within the building sector. Smart metering programs, a cornerstone of the EU's energy policy, have emerged as a transformative strategy to empower consumers with real-time information about their energy usage [5]. This discourse delves into the pivotal role of smart metering programs within the context of energy efficiency across EU MSs, elucidating their objectives, mechanisms, and implications.

Smart metering programs are driven by the fundamental objective of revolutionizing how individuals and businesses consume energy. By providing real-time data on energy usage, these programs aim to heighten consumer awareness, enable informed decision-making, and foster responsible energy behaviours [6]. In the context of the building sector, where energy consumption is substantial, smart metering programs hold significant promise for reducing wastage and promoting sustainable practices.

Central to the effectiveness of smart metering programs is their capacity to deliver real-time energy consumption data to consumers. Through digital interfaces and mobile applications, users gain immediate insights into their energy usage patterns, empowering them to identify consumption peaks, optimize usage schedules, and make informed adjustments to mitigate energy wastage [7]. This empowerment shifts energy consumers from passive recipients to active participants in energy conservation efforts.

Smart metering programs leverage behavioural psychology principles to drive desired energy consumption behaviours. By fostering an understanding of the direct correlation between actions and energy costs, consumers are incentivized to make energy-efficient choices. Moreover, the implementation of demand response mechanisms allows utilities to communicate peak energy usage periods to consumers, encouraging them to curtail consumption during times of strain on the energy grid.

The implementation of smart metering programs raises pertinent concerns about consumer privacy and data security. To address these concerns, EU MSs have put in place stringent regulations that govern data collection, storage, and usage [8]. Transparent communication of data handling practices and the provision of opt-out options ensure that consumer rights are upheld while reaping the benefits of data-driven energy management.

Smart metering programs hold far-reaching societal and environmental implications. On a societal level, these programs promote a sense of individual agency and shared responsibility toward energy conservation, fostering a culture of sustainability. Environmentally, the cumulative effect of reduced energy consumption resulting from informed decision-making contributes to lower greenhouse gas emissions, aligning with the EU's broader environmental commitments.

The evolution of smart metering technology continues to introduce innovative features such as real-time pricing, integration with smart home systems, and two-way communication capabilities [9]. These advancements enable deeper consumer engagement, automate energy-saving actions, and enhance the integration of renewable energy sources into the grid.

In conclusion, smart metering programs constitute a fundamental strategy in the EU MSs' efforts to enhance energy efficiency within the building sector. By granting consumers access to real-time energy consumption data and promoting conscious energy behaviours, these programs empower individuals to play an active role in the transition toward a sustainable energy future. As technological advancements continue to unfold, the potential of smart metering to reshape energy consumption habits and mitigate environmental impact remains a beacon of promise for the EU and beyond.

3.4 Energy Efficiency Certifications

Energy efficiency certifications have emerged as a potent tool to incentivize and regulate sustainable practices within the building sector. This discourse delves into the significance of energy efficiency certifications within the context of EU MSs, elucidating their objectives, standards, and potential contributions to a greener and more sustainable future.

Energy efficiency certifications serve a dual purpose: to set clear benchmarks for building energy performance and reward compliance with these benchmarks. The overarching objective is to instigate a paradigm shift in the construction and operation of buildings, promoting energy-efficient designs, technologies, and practices [10]. By recognizing and endorsing structures that adhere to rigorous efficiency criteria, certifications elevate the role of sustainability in building development.

Energy certifications are underpinned by standardized methodologies that assess and quantify the energy performance of buildings. The establishment of these methodologies enables a consistent evaluation of energy consumption, thermal insulation, lighting efficiency, and other relevant parameters [11]. Through standardized metrics, such as energy use intensity or carbon emissions per square meter, certifications facilitate easy comparison and benchmarking of buildings' sustainability.

EU MSs have introduced diverse certification schemes and labels encompassing various energy efficiency aspects. Notable examples include the Leadership in Energy and Environmental Design (LEED) [12] and Building Research Establishment Environmental Assessment Method (BREEAM) [13] certifications. These schemes evaluate elements ranging from architectural design and construction materials to heating, ventilation, and air conditioning systems, providing a comprehensive assessment of a building's environmental impact.

They introduce a market-driven incentive structure by awarding higher values to buildings that achieve higher energy performance levels. This stimulates demand for sustainable design and construction practices, encouraging developers to invest in energy-efficient technologies and strategies. Certifications confer prestige upon certified buildings and enhance their market value by appealing to environmentally conscious consumers. Furthermore, they transcend energy consumption considerations, incorporating a holistic view of sustainability. Factors such as water efficiency, indoor air quality, and proximity to public transportation are evaluated in tandem with energy performance. This comprehensive approach underscores the interplay between energy efficiency and broader sustainability goals.

In addition to market-driven incentives, energy efficiency certifications align with regulatory frameworks and policy objectives set by EU MSs. Mandatory compliance with certain certification standards for new constructions or significant renovations ensures the integration of sustainability into building development practices. This regulatory alignment cements the role of certifications as vehicles for policy implementation and enforcement.

Energy efficiency certifications are poised to contribute significantly to the realization of net-zero energy buildings, where the energy consumed by a building is offset by renewable energy generation on-site or off-site. By necessitating renewable energy integration and stringent efficiency measures, certifications drive the building sector toward unprecedented levels of sustainability.

By setting rigorous energy performance standards, incentivizing sustainable practices, and aligning with policy objectives, these certifications propel the building sector toward a future defined by energy efficiency, environmental stewardship, and reduced carbon footprint [14]. The convergence of energy efficiency certifications with broader sustainability agendas heralds a transformational era in which buildings are not only functional and aesthetically appealing but also vital components of a resilient and ecologically conscious urban fabric.

3.5 Renewable Energy Incentives

In the pursuit of a low-carbon and sustainable energy future, EU MSs have embraced a comprehensive array of strategies to encourage the adoption of renewable energy sources within the building sector. Among these strategies, renewable energy incentives have emerged as pivotal tools to drive the transition towards cleaner and more sustainable energy systems. This discourse delves into the significance of renewable energy incentives within the context of EU MSs, elucidating their objectives, mechanisms, and potential contributions to a greener building sector.

Renewable energy incentives are designed with a fundamental objective: to accelerate the deployment of renewable energy technologies, such as solar panels, wind turbines, and geothermal systems, within the building sector [15]. At the core of these incentives lies the recognition of the environmental imperative to reduce greenhouse gas emissions and mitigate the adverse impacts of climate change. By promoting the integration of renewable energy sources, these incentives align with the EU's broader sustainability goals.

One of the primary mechanisms employed by EU MSs to encourage renewable energy adoption is the provision of financial incentives and subsidies. These incentives alleviate the upfront costs associated with installing renewable energy systems in buildings. Subsidies can take various forms, including grants, tax credits, rebates, and feed-in tariffs, all of which reduce the financial burden on individuals, businesses, and developers, thereby fostering higher adoption rates.

Feed-in tariffs and net metering mechanisms are particularly noteworthy in promoting renewable energy in the building sector. Feed-in tariffs guarantee fixed payments to renewable energy producers for the electricity they generate and feed into the grid. Net metering allows building owners to offset their energy consumption by exporting excess energy generated from renewable sources, resulting in reduced energy bills and enhanced economic viability.

Many EU MSs offer additional incentives through green building certification programs [16]. Buildings that achieve high levels of renewable energy integration and energy efficiency can qualify for special certifications, such as LEED or BREEAM, which confer prestige and additional benefits. These certifications often serve as indicators of a building's commitment to sustainability and can influence property values and marketability.

EU MSs also prioritize research and innovation within the renewable energy sector. Financial support for research projects, technology development, and innovation incubators fosters the advancement of renewable energy technologies [17]. These initiatives catalyze the development of cutting-edge solutions that can be seamlessly integrated into the building sector.

Renewable energy incentives are often extended to the community level, encouraging the participation of neighbourhoods, municipalities, and local cooperatives in sustainable energy generation. Shared solar projects, community wind farms, and collective purchasing programs enable citizens to invest in renewable energy projects collectively, fostering a sense of ownership and collective responsibility.

Renewable energy incentives are strategically aligned with EU policies, including the Renewable Energy Directive, which sets binding targets for the share of renewable energy in the overall energy mix. By

fostering renewable energy deployment, MSs contribute to the achievement of these targets, enhancing energy security and reducing dependency on fossil fuels.

In conclusion, renewable energy incentives stand as catalysts for the transformation of the building sector in EU MSs. These incentives accelerate the shift towards cleaner and more resilient energy systems by mitigating financial barriers, promoting innovation, and aligning with broader sustainability agendas. As the building sector increasingly embraces renewable energy sources, the convergence of incentives with evolving technologies and policy frameworks heralds a promising era of sustainability, resilience, and reduced environmental impact.

4 Documentation of existing incentives and penalty schemes

4.1 EU member state findings on energy policy frameworks

Within the realm of advancing energy efficiency, a meticulous investigation was undertaken to scrutinize prevailing energy-efficient schemes across EU MSs. This analytical endeavour delved into the intricacies of existing incentives and penalty structures operating within a country-specific context [18]. This multifaceted analysis served a dual purpose, namely the identification of potential overlaps and the elucidation of challenges encountered during the operationalization of these schemes. The countries that were subjected to rigorous scrutiny encompassed a diverse array, including:

- Cyprus
- Greece
- Netherlands
- Germany
- France
- Spain
- Austria
- Slovakia
- Denmark
- Estonia

The data collection phase emanated from an assortment of secondary sources. These encompassed an array of scholarly publications, government documents, industry reports, and reputable online databases. The utilization of secondary data allowed for an all-encompassing panoramic view, enabling the aggregation of insights from diverse domains within the energy sector.

This granular analysis sought to unveil both the nuances and overarching themes prevalent within each state's scheme. The primary focus lay on the identification of commonalities—occurrences where multiple countries exhibited similar strategies—and distinctions—instances where divergence in approaches was observed.

The analysis unveiled remarkable instances of convergence among MSs. Certain strategies, it was discerned, exhibited cross-border prevalence. This discovery bears profound implications, hinting at such strategies' potential efficacy and adaptability across varied geopolitical landscapes. It was noteworthy that such overlaps did not merely signal homogeneity but, rather, the acknowledgement of successful paradigms worthy of emulation.

While commonalities were identified, so too were distinctive challenges and discrepancies. These disparities illuminated the dynamic interplay between policy formulation and real-world implementation. By addressing these issues head-on, the conscientious energy user schemes developed within the D^2EPC project aimed to circumvent historical hurdles, ensuring a higher likelihood of success in their execution.

The dissection of these energy policy frameworks did not merely serve a retrospective function; it was an intellectual vantage point that informed the innovative approach of the D^2EPC project. The past experiences of MSs laid the groundwork for strategic innovation, enabling the incorporation of successful elements while circumventing the pitfalls that might have previously impeded progress.

In conclusion, the analysis of existing incentives and penalty schemes across EU MSs furnished a robust foundation for the subsequent development of motivational schemes targeting conscious energy users within the building sector. This exploration unearthed both unifying themes and distinctive challenges, encapsulating a wealth of insights that fuelled innovation and substantiated the endeavours of the D^2EPC consortium in creating impactful and efficacious energy policies.

4.1.1 Austria

The year 2021 marked a significant juncture in Austria's commitment to sustainable progress, with the ratification of the Austrian National Recovery and Sustainability Plan (NRRP) in June. Underpinning this strategic framework is a multifaceted approach to address crucial energy-related concerns and champion socio-economic resilience. Central to the NRRP's blueprint is the allocation of funds to enhance building infrastructure, particularly pertaining to energy efficiency.

Building upgrades are only partially funded under the plan. Low-income homes are targeted by NRRP housing initiatives, which pay up to 80% of the cost of heat rehabilitation and replacement; therefore, 50 million euros have been set aside to combat energy poverty. Thermal repair and modernization of heating systems may be included in the investment for energy poverty, which is planned to help 2,250 family dwellings by 2025. Projects must achieve a 30 % average decrease in primary energy savings to be eligible for financing. Oil boilers are also under the prohibition [19].

4.1.1.1 Recovery and Resilience Plan Austria

Austria's dedication to progress is vividly reflected in its allocation of substantial resources for the nation's recovery and resilience endeavors. With an anticipated budget of €4,449,475,001, amounting to 1.2 % of the nominal economic production in 2020, the Recovery and Resilience Fund (RRF) emerges as a cornerstone for transformative change [20]. Within this ambitious framework, €3.5 billion will be channeled as grants to bolster Austria's developmental aspirations.

4.1.1.2 Renovation Wave and Energy Transition Initiatives

An integral facet of Austria's transformative strategy is the "Renovation Wave," a subcomponent earmarked with a budget of €209 million. This initiative underscores two pivotal objectives: firstly, fostering the green transition by facilitating the replacement of environmentally detrimental oil and gas heating systems with renewable alternatives, and secondly, fortifying social resilience by addressing energy costs in low-income households through comprehensive thermal dwelling renovations.

- Renewable Heating Law

Positioned as a catalyst for modernization, the Renewable Heating Law lays the foundation for the phased replacement of outdated heating systems. With a focus on newly constructed buildings, this legal framework mandates the gradual elimination of fossil fuel heaters by 2025, incentivizing their substitution with renewable energy sources or district heating options.

- Exchange of Oil and Gas Heating Systems

Austria's commitment to sustainable transformation is palpably evident through its investment in exchanging oil and gas heating systems. This financial impetus, totalling €158.92 million, aims to enhance the prevalence of renewable energy heating systems in residential domains. By reducing energy consumption linked to heating, mitigating greenhouse gas emissions, and curbing air pollution, this initiative resounds with environmental stewardship.

The financial assistance program targeted at private individuals, encompassing around 31,800 households, exemplifies Austria's dedication. These households are offered support to transition from fossil fuel heating to environmentally friendly alternatives such as biomass-based heaters, heat pumps, or district heating connections. The deadline for implementation is set for June 30, 2026.

Austria's commitment to holistic transformation extends to the corporate sphere. The General Investment Premium Scheme for Firms allocates €205.5 million for stimulating thermal

refurbishments, renewable energy integration, and energy-saving measures within corporate infrastructure.

- Combating Energy Poverty

In the relentless pursuit of energy optimization, Austria earmarks €50 million to combat energy poverty. This laudable initiative aims to ameliorate energy usage within buildings, particularly focusing on low-income households susceptible to energy poverty. The strategy involves the comprehensive thermal rehabilitation of around 2,250 homes, many characterized by economic constraints.

Integral to this initiative is an integrated support scheme tailored to provide personalized assistance and financial aid for family dwelling renovations. This comprehensive program encompasses diverse aspects such as thermal insulation, window and heater replacements, and expert planning guidance. Collaboration with social NGOs is also anticipated, emphasizing consultation services and the elevation of awareness as key components of the initiative's execution.

In conclusion, Austria's concerted efforts under the National Recovery and Sustainability Plan epitomize a holistic commitment to sustainable development. By integrating initiatives like the Renovation Wave and strategic investments in energy transition, Austria establishes itself as a vanguard in fostering socio-economic resilience while aligning with green imperatives.

4.1.2 Cyprus

The Republic of Cyprus has proactively embraced a triad of robust initiatives to propel energy efficiency within its borders. Notably, one of the most pivotal plans, titled 'Εξοικονομώ-Αναβαθμίζω τις κατοικίες' (Save-Upgrade Housing), has been meticulously laid out for execution between 2021 and 2027. This groundbreaking plan, which saw its inaugural announcement in March 2021, was endowed with an impressive budget of 30 million euros, all earmarked for a singular objective: the comprehensive enhancement of energy efficiency in pre-existing residential structures [21].

The central facet of this plan revolves around the profound transformation of existing homes through energy upgrades of a significant magnitude. These enhancements encompassed the holistic replacement and installation of novel materials and equipment, a pivotal measure to actualize the overarching energy efficiency goals.

Dwelling deeper into the details, this transformative endeavour hinged on the fulfilment of five crucial criteria, each meticulously crafted to ensure that the funds are channeled effectively and efficiently:

- Electricity Account Prerequisite: Eligibility necessitates an active electricity supply account sanctioned by the Cyprus Electricity Authority (CEA).
- Chronological Application Clause: The building in question must have submitted its planning permission application on or before December 21, 2007.
- Geographical Scope: The geographical scope extends exclusively to buildings situated within the territorial precincts of the Republic of Cyprus.
- Energy Efficiency Index: A pivotal determinant for funding qualification is an energy efficiency rating of C or lower for the dwelling in question.
- Exclusive Funding Qualification: The building should not have been previously approved for any other financial grants.

Parallel to this substantial initiative, the Renewable Energy Sources (RES) and Energy Saving (EXE) funds orchestrate sponsorship programs tailored to installing or substituting solar systems designed to generate domestic hot water. This dual-pronged approach aims to facilitate solar system adoption (plan 1) and enable the replacement of electric appliances in the domiciles of the vulnerable segments (plan 2).

4.1.2.1 Eligibility Criteria

The following criteria must be met for households to be eligible for the installation or replacement of solar systems for the production of domestic hot water funding:

- Holistic Solar Systems: Eligibility hinges on the integration of comprehensive solar systems encompassing cylinders and frames.
- Chronological Imperative: Planning permission application must be dated on or before December 21st, 2007.

These multifaceted enhancements and pivotal initiatives are made possible through funding stemming from the European Union's 'Next Generation EU' initiative. Within this framework, a commendable budget of 600,000 euros has been allocated, with a strategic differentiation in allowances—900 euros for residences nestled in mountainous regions and 450 euros for those located in non-mountainous areas.

The energy enhancements are compartmentalized into three distinctive categories, each epitomizing a unique pathway toward energy efficiency [22]:

- Enhancement sans Photovoltaics: Shell thermal insulation uplifted by two-thirds, devoid of photovoltaic integration.
- Holistic Upgrade with Photovoltaics: A paradigm that embraces a new photovoltaic certification of energy efficiency, coupled with a two-thirds enhancement of shell thermal insulation.
- Near Zero Energy Consumption Enhancement: The apogee of energy efficiency, characterized by an energy efficiency certificate rating of A, comprehensive shell thermal insulation, and an impressive 25% reliance on renewable energy sources for consumption.

In conclusion, through judicious orchestration of innovative plans and strategic funding, Cyprus has embarked on an ambitious journey to revolutionize energy efficiency within its residential fabric. By meticulously aligning legislative criteria, geographical nuances, and holistic enhancements, Cyprus aims to usher in an era of conscientious energy consumption that not only addresses contemporary imperatives but paves the way for sustainable living on a national scale.

4.1.1 Denmark

In a resolute stride towards catalyzing a sustainable and environmentally-conscious resurgence, the Danish government has ushered in a visionary paradigm that earmarks substantial financial resources. An impressive allocation of 30 billion Danish kroons (equivalent to EUR 4 billion) has been strategically directed towards orchestrating profound ecological enhancements within the ambit of the social housing sector. This groundbreaking program, underpinned by an ethos of ecological mindfulness, stands as an exemplar of proactive governance in the face of pressing environmental concerns.

The core of this program revolves around a concerted endeavour to rejuvenate ageing residential structures, harmonizing them with contemporary energy standards. A multifaceted strategy is being employed to holistically refurbish these domiciles, with an emphasis on bolstering their energy efficiency quotient [23]. The transformation is orchestrated through a meticulous orchestration of measures, prominently including the meticulous insulation of external walls, roofs, and ceilings. An equally transformative intervention is the systematic replacement of antiquated windows with cutting-edge, energy-efficient counterparts. This collective spectrum of interventions bears a momentous

consequence—an impressive reduction in heat dissipation, quantified at an impressive range spanning between 30% and 40%.

The real-world implications of this visionary initiative are both tangible and far-reaching. In practicality, the Danish program reverberates with a profound promise of significant ecological redemption. Notably, the impending reduction in carbon dioxide (CO_2) emissions bears a numerical magnitude of 50,000 tonnes—an accomplishment that resonates with broader global aspirations for carbon footprint mitigation [24]. Moreover, the energy consumption landscape is poised to undergo a seismic shift, with a discernible diminution of a staggering 500 gigawatt hours. To contextualize this prodigious achievement, this quantum of energy is tantamount to the heat consumption necessitated by 40,000 conventional apartments in regular usage.

This Danish endeavour is more than a mere policy enactment; it embodies a transformative archetype—a testament to the potential synergy between proactive governance and ecologically conscious progress. The tangible outcomes of this program underscore a pivotal juncture in the pursuit of sustainable development, and its implications ripple beyond geographical confines. As the world navigates the intricate labyrinth of environmental stewardship, the Danish case study emerges as a guiding light, illuminating a pathway toward pragmatic solutions that decisively tackle the imperatives of energy efficiency and carbon neutrality.

4.1.1 Estonia

In the annals of sustainable energy advancement, a pioneering program emerged in Estonia that set a resounding precedent for fostering conscious energy usage. In the year 2001, the inception of KredEx marked a watershed moment, orchestrating an exceedingly triumphant initiative that reverberates to this day. The bedrock of KredEx lies in its multifaceted approach, where not only financial incentives but also technical support galvanize citizens toward substantial energy enhancements, primarily concentrated within multi-family apartment complexes.

KredEx emerged as an avant-garde financial assistance program that found its genesis in Estonia [25]. This groundbreaking endeavour catalyzed a paradigm shift by amalgamating technical support, loans, and finance guarantees into a comprehensive framework. These collective incentives were methodically tailored to inspire the Estonian populace to embark upon momentous energy enhancements within their residential abodes, with a pronounced emphasis on multi-family apartment structures.

In an era where transformative innovation beckoned, the imprimatur of the European Bank for Reconstruction and Development and the imbuement of the European Social Fund bestowed KredEx with an indelible mark of credibility and financial underpinning. This dual endorsement conferred a seal of approval, elevating KredEx to a position of prominence and rendering it a recipient of funds channelled through official corridors.

KredEx embraced a holistic ethos, embracing a multifaceted suite of benefits to empower building owners on their energy efficiency journey. A strategic trifecta encompassed grants, loans, and technical support. Pertinently, building owners were extended grants encompassing up to 50% of energy audit expenses and project documentation drafting costs. Moreover, a progressive support structure was devised, allocating up to 35% assistance for reconstruction endeavours. The resonant ethos rested on not only a singular dimension of financing but also a synergistic fusion to amplify energy-centric initiatives [24].

The impact of KredEx proved to be momentous, reverberating across the Estonian landscape. KredEx buoyed an astounding 103,000 families in their pursuit of home renovations infused with energy efficiency. This concerted effort led to a striking average energy savings of nearly 40% across the

entirety of the renovated portfolio. Such accomplishments underscore the tangible influence and sustainable benefits underpinning KredEx's ethos.

The emblematic success stories that adorn KredEx's legacy spotlight instances where outcomes transcend expectations. Evidently, energy consumption underwent a seismic 65% reduction post-refurbishment in select projects. This serves as a testament to the transformative potential of meticulous renovations and energy-conscious interventions.

A pivotal facet accentuating KredEx's distinction lies in its progressive loan structure that scales with the magnitude of energy-saving objectives. A perceptive tiered approach ensures that the loan quantum is commensurate with the ambition of energy conservation. Notably, the average loan amount per project has eclipsed €200,000, signalling both the program's comprehensive support and the audacity of energy-centric ambitions.

KredEx's impact radiates through a spectrum of measures that crystallize the synergy between sustainable progress and innovation. This entails roof and wall insulation, strategically replacing windows and doors, ushering in novel heating systems, integrating heat recovery ventilation systems, embracing ground-source heat pumps and biomass boilers, and strategically integrating building energy management systems. This holistic approach underscores KredEx's commitment to orchestrating holistic transformations.

Estonia's visionary initiative, encapsulated within the folds of KredEx, is an exemplar of how financial incentives, technical support, and collective aspirations can synergize to engender profound energy-conscious change. KredEx's footprint endures not only within the edifices it transformed but as an indelible lesson in how visionary approaches to energy efficiency can illuminate the path toward a sustainable future.

4.1.1 France

At the forefront of France's pioneering endeavours in fostering energy efficiency within its residential sector stands the remarkable Certificat d'économie d'énergie (CEE) program. As a dynamic initiative, the CEE program orchestrates a collaborative dance between the country's prominent energy suppliers, including esteemed entities such as EDF, Engie, and TotalEnergies. This distinctive program not only exhorts energy suppliers to attain CEE certification but ingeniously intertwines the enforcement of financial penalties as a countermeasure for non-compliance. This strategy's core motivation is to channel the financial resources accrued through penalties into transformative remodelling projects. These projects, in turn, aim to elevate the energy efficiency quotient of residential buildings, orchestrating a harmonious symphony of environmental and infrastructural advancement.

A distinguishing facet of the CEE program surfaces in its inclusivity, particularly in its resolute efforts to extend its impact to low-income families. As a beacon of equitable sustainability, this initiative extends a helping hand in the form of additional financial aid to economically challenged households. This catalytic support serves as a bridge to traverse the chasm that sometimes separates aspiration from implementation. The beauty of this provision lies in its flexibility, for its utilization spans a wide spectrum of possibilities. From comprehensive renovations that encompass a holistic transformation of living spaces to nuanced alterations such as bolstering insulation, upgrading boilers, or enhancing heating systems—the canvas for improvement remains vast and versatile [26].

The hallmark of any transformation, however, rests in its measurable impact. Herein, the CEE program unveils a profound stipulation, an evaluative benchmark that mirrors its commitment to substantive change. The imperative guiding refurbishments are unequivocal: to achieve a remarkable reduction in energy consumption. A commendable 55% reduction in energy usage is the prescribed threshold for individual dwellings, whereas shared properties within apartment complexes embrace a laudable goal

of a 35% reduction [27]. These schemes are for properties that are at least two (2) years old. As a masterstroke, this criterion not only embodies the aspirations of sustainability but also grounds them in a pragmatic framework.

It is imperative to recognize that the ambit of this program's benevolence extends to a diverse array of stakeholders. Property owners, whether they are custodians of primary abodes or secondary retreats, are poised to harness the transformative potential embedded within the CEE program. The tapestry of beneficiaries is further enriched by encompassing landlords and tenants alike. The underlying philosophy is inclusivity— bridging disparities and transcending boundaries to usher forth a collective metamorphosis.

The narrative of the CEE program also finds resonance in its synergy with parallel incentives and governmental grants. This strategic alignment elevates the potential impact exponentially, creating a harmonious convergence of financial support mechanisms. The holistic orchestration of such synergies serves as a testament to the program's integration within the broader tapestry of sustainability initiatives, accentuating its role as a pivotal player in the symphony of energy efficiency.

In essence, the Certificat d'économie d'énergie (CEE) program emerges as an exemplar of collaborative ingenuity, embodying the spirit of partnership between energy suppliers, beneficiaries, and governmental entities. Through its multifaceted approach, from penalties to incentives, from comprehensive transformations to incremental enhancements, the program stands as a resounding testament to France's commitment to a more energy-conscious and environmentally harmonious future.

4.1.2 Germany

The inception of the Bundesförderung für Effiziente Gebäude (BEG) program in Germany marked a pivotal stride toward promoting sustainable building practices and nurturing energy-efficient transformations. Initially introduced in January 2021 under the banner of Energy-Efficient Construction and Refurbishment (Kreditförderung - KfW), this program underwent a notable evolution by July of the same year. During this transformative phase, the German government took a momentous decision: to extend additional subsidies for energy-efficient buildings, thereby accentuating an array of incentives designed to catalyze transformative change. The measures address the following aspects:

- Residential buildings
- Non-residential buildings
- Individual measures

The ambit of BEG's initiatives extends across both residential and non-residential domains, embodying a comprehensive approach to engendering energy efficiency. The program adeptly navigates the intricate landscape of the real estate, encompassing both new constructions and revitalization endeavours undertaken to enhance energy efficiency [28]. This inclusivity underscores the program's commitment to addressing diverse dimensions of energy conservation.

4.1.2.1 Funding for home modernizations:

A distinctive facet of BEG's strategy lies in its focus on individual measures, embracing targeted interventions that uphold energy conservation. This is exemplified by initiatives such as the replacement of draft doors and windows with their insulating counterparts and fine-tuning energy efficiency at a micro level. The program's inclination towards precision over sweeping mandates demonstrates its astute approach to resource optimization.

It is essential to underscore the universality of BEG's funding schemes. Contrary to any notions of exclusivity, the program extends its reach to encompass German citizens and anyone with a vested interest in acquiring property within the country's borders. This approach, borne out of a commitment to collective environmental stewardship, demonstrates an open-armed approach to international collaboration in the pursuit of energy efficiency.

4.1.2.2 Funding for energy-efficient house purchases

In recognizing the significance of modernizing existing homes, BEG's funding program takes a pivotal role. Homeowners seeking to elevate their properties to the echelons of energy efficiency are empowered to directly access the program through KfW. The financial provisions are poised to support a spectrum of interventions:

- Up to 20% coverage by the government for changing draft doors and windows
- 20% funding for installing digital heating systems and insulating facades and roofs
- 20 to 40% coverage for investments in renewable energy heating systems
- 50% coverage for the replacement of oil heating systems
- Empowering Homebuyers: A Path to Energy-Efficient Homes

The BEG program extends its embrace to prospective homeowners as well, offering low-interest loans and repayment subsidies to expedite the acquisition of energy-efficient residences. This is underscored by three distinct energy-efficiency building standards: Efficiency House 55, Efficiency House 40, and Efficiency House 40 Plus.

Central to BEG's approach is the numerical quantification of energy efficiency, as encapsulated by these aforementioned efficiency house standards. These figures operate as a touchstone for understanding a structure's energy efficiency. A lower numerical value corresponds to heightened energy efficiency and subsequent accessibility to enhanced financing.

The BEG program encapsulates Germany's resolute commitment to fostering energy efficiency within its built environment. It is a beacon of transformative change, offering a spectrum of financial incentives catering to existing homes and new constructions. Germany sets a precedent for other nations through this intricate tapestry of measures, exemplifying the intricate symbiosis between policy, sustainability, and conscientious energy consumption.

4.1.3 Greece

A notable exemplar within the intricate tapestry of energy-efficient initiatives can be observed through Greece's commendable efforts in the realm of sustainable energy utilization. The Greek landscape is enriched by two pioneering programs, namely 'Saving at Home' and 'Saving 2021'. This pioneering endeavour has been allocated a substantial budget of 1.6 billion euros, underscoring the nation's commitment to fostering a culture of energy consciousness and environmental stewardship.

4.1.3.1 The 'Saving at Home' Program

The 'Saving at Home' program stands as a beacon of sustainability with a comprehensive scope and far-reaching impact. Imbued with a pronounced fiscal commitment, this program has been designed to address the multifaceted challenges encompassing energy efficiency within the domestic sphere. The program's holistic approach seeks to transform individual households into hubs of energy conservation, thereby contributing collectively to Greece's broader sustainability goals. Although further granularity is required to expound on the intricacies of this initiative comprehensively, its significance lies in its potential to ameliorate energy consumption patterns across the nation tangibly.

4.1.3.2 The 'Saving 2021' Program: Precision in Implementation

A nuanced facet of Greece's energy endeavours is encapsulated within the 'Saving 2021' program, endowed with a budget of 100 million euros. This specific program is not only substantial in monetary allocation but is also strategically tailored to meet predefined targets. The ambitious aim of subsidizing up to 105,000 inhabitants by the year 2025 underscores Greece's commitment to meticulous planning and impactful execution.

The 'Saving 2021' program exhibits a sophisticated approach, offering two distinct applications catered to varying housing unit typologies. The differentiation between individual apartments or detached houses and entire apartment buildings is indicative of the program's granularity and contextual relevance. This bespoke approach recognizes the diversity within the housing landscape and strives to provide tailored incentives for each category [29].

Aligned with Greece's stringent commitment to both efficiency and effectiveness, the 'Saving 2021' program introduces a set of eligibility criteria. These prerequisites not only serve as gatekeepers to ensure the targeted impact but also safeguard the program's alignment with overarching sustainability objectives:

- Legitimate Property Status: The fundamental requirement necessitates that the property in question must possess legal status, thereby eliminating potential legal complications and ensuring the credibility of program participants.
- Exclusion of Demolishable Properties: Properties earmarked for potential demolition are consciously excluded from eligibility, a strategic move that prevents futile investment in energy-efficient upgrades for structures deemed unsalvageable.
- Primary Residence Utilization: A critical criterion mandates that the property must serve as the primary residence, aligning the program's benefits with households directly invested in optimizing their energy footprint.
- First Energy Efficiency Certificate (EEC) Compliance: A pivotal facet revolves around the property's Energy Efficiency Certificate. To qualify, the property must possess an EEC rating equivalent to level C or below. This judicious stipulation ensures that the program's benefits are channeled towards properties with genuine potential for energy optimization.

4.1.4 The Netherlands

Within The Netherlands, a compelling impetus towards fostering energy efficiency initiatives has been marshalled by the central government. This impetus encompasses not only residential properties but also extends its ambit to encompass rental properties, drawing upon an intricate framework of loans and grants. This multifaceted approach, orchestrated by the Dutch government, encapsulates an array of targeted measures aimed at propelling energy conservation within the residential landscape [30].

At the heart of this drive lies the central Dutch government, functioning as a veritable powerhouse in steering energy-saving initiatives. This governmental agency has harnessed a comprehensive toolkit comprising both financial and structural instruments. These encompass loans and grants tailored to encompass a diverse spectrum of facets, ranging from quintessential aspects such as roof insulation and façade enhancement to the integration of solar water heating, heat pumps, and energy-efficient ventilation systems replete with heat recovery mechanisms.

A paramount aspiration of the Dutch government is the radical enhancement of energy efficiency across the spectrum of buildings. This ambitious vision crystallizes into tangible outcomes, manifesting in a resolute goal to retrofit a staggering 300,000 residences, inclusive of rental properties and assorted

structures annually. This formidable endeavour transpires through formalized agreements orchestrating seamless collaboration between the construction, engineering, and energy industries.

The dynamic landscape of energy efficiency unfolds through the prism of a localized synergy. In pragmatic terms, this translates to a notable assembly of 14 distinct projects wherein regional governmental bodies and private enterprises forge alliances. These alliances converge upon a shared aspiration: the amelioration of energy efficiency within no less than 33,500 domiciles. The stratagem at play entails an intricate 'block-by-block' approach, meticulously designed to curtail expenses while maximizing the reach and effectiveness of interventions.

Within this overarching endeavour, rental properties occupy a distinctive echelon. A duo of schemes tailored to encourage landlords in the pursuit of energy efficiency manifests within this niche. The Energy Performance Incentive Scheme for the Rental Sector (STEP) [31] emerges as a pivotal cornerstone, extending a compelling incentive framework to landlords. This framework ardently encourages the metamorphosis of rental abodes into veritable bastions of energy efficiency.

The stratagem of financial facilitation conjoins with the Energy Savings Fund for the Rental Sector (FEH), constituting a pioneering initiative. This initiative is predicated on the provision of low-interest loans to landlords who evince a commitment to augmenting the energy efficiency quotient of their rental edifices. This symbiotic relationship between financial incentives and energy conservation charts an innovative pathway, fostering mutually beneficial outcomes for both property owners and the broader ambit of energy conservation.

The Netherlands' concerted efforts to galvanize energy efficiency initiatives constitute a remarkable manifestation of governmental commitment. With a multifaceted repertoire of loans, grants, and collaborative agreements, the country stands poised at the threshold of a transformative journey toward holistic energy efficiency. This transformative trajectory, bolstered by localized collaborations and innovative financial incentives, underscores the potency of synergistic endeavours in realizing energy-conscious aspirations within the built environment.

4.1.1 Slovakia

Within the context of the Slovak Republic, an ambitious initiative has been undertaken to transform the landscape of older family residences. The focal intent of this endeavour is to ensure the longevity and vitality of a significant portion of the housing infrastructure. Specifically targeting the renovation of at least 30,000 households between the years 2022 and 2026, this initiative resonates with a profound commitment to sustainable living and enhanced energy efficiency. A transformative shift is envisaged by channelling efforts into bolstering the thermal attributes of these dwellings, coupled with the replacement of obsolete heat and hot water sources with cutting-edge, high-efficiency alternatives.

The cornerstone of this transformational journey rests upon a holistic approach that transcends mere surface enhancements. In addition to upgrading the building envelope's thermal properties, the initiative advocates for the integration of contemporary ventilation systems. These systems, leveraging renewable energy sources and repurposed waste heat, herald a pioneering step towards fostering optimal indoor environmental quality. This convergence of sustainable technology and building renovation reflects a concerted effort to synergize comfort and ecological responsibility.

Embedded within the strategic fabric of this endeavour is an unwavering commitment to climate consciousness. A pivotal directive mandates that a substantial proportion of spending aligns with climate-related imperatives. Notably, this directive is not just a nominal commitment; it is robustly exemplified in the Slovak Recovery Plan. A remarkable allocation of up to 43% of total spending is

earmarked for climate-related undertakings—a testament to Slovakia's steadfast dedication to sustainability.

To facilitate the realization of this vision, substantial financial resources have been allocated. A considerable fund of $528.2 million stands designated for the comprehensive restoration of 30,000 individual-family homes by 2026 [32].

Equally paramount is the stipulation that the initiative resonates with the aspirations and endeavours of individual citizens. The eligibility criteria reinforce this notion, mandating that the applicant for this initiative be a natural person who holds legal ownership of a family home, as substantiated by an official title deed. This criterion underscores the alignment of this endeavour with individual citizens who are deeply vested in the welfare of their homes and the sustainable evolution of their communities.

Recognizing the diverse spectrum of property ownership, the initiative demonstrates a pragmatic orientation. In scenarios where a family home bears the mantle of co-ownership, the applicant is designated as an individual who possesses the explicit endorsement of all co-owners [33]. This approach not only streamlines the application process but also fosters a sense of collective ownership and engagement.

In conclusion, the renovation of family houses in Slovakia transcends the boundaries of mere infrastructure enhancement. It is a testament to the nation's commitment to sustainable living, energy efficiency, and climate-conscious fiscal prudence. Slovakia's path of transformation underscores the significance of individual ownership and collaboration in manifesting a future that amalgamates comfort, sustainability, and community well-being.

4.1.2 Spain

The Spanish government has set aside 5.8 billion euros for various building rehabilitation projects, with an emphasis on energy efficiency. Direct subsidies of up to three quarters of the cost of works such as thermal insulation, enhanced lighting, solar panel installation, and more efficient heating, hot water, and cooling systems are available under PREE 5000. The National Integrated Energy and Climate Plan 2021-2030 has previously set the aim of improving the energy efficiency of 1.2 million houses.

This program is for both individuals and legal entities, as well as private residences and companies, as well as any public or private property in need of updating. It expressly covers building renters, operators, and concessionaires. Homeowners' associations and local energy communities (neighbourhoods, blocks, or other collectives sharing renewable energy infrastructure, such as solar photovoltaic systems) are also eligible [34].

The program supports two categories of municipalities: those with a population of up to 5,000 people and those with a population of more than 5,000 people. Those having a population of up to 20,000 people but fewer than 5,000 people in specific population centers, such as parishes, are included on the Demographic Challenge map. Insulation, renewable energies, and energy-efficient lighting are the three major components of the assistance [35].

Thermal insulation is the first type. Improvements to insulation, exterior carpentry, glass, air chambers, and even nearby parts like greenhouses are all possible. Direct subsidies will be 50% for full buildings and 40% for individual residences or premises, with extra percentages of up to 25% based on energy savings achieved, the beneficiary's unique social conditions, or if the action is part of a larger package.

Increased energy efficiency and the replacement of traditional energy sources with renewable energy sources is the second type. Heating, air conditioning, refrigeration, ventilation, and hot water systems are all examples of HVAC systems. Photovoltaic solar panels, geothermal, hydrothermal, and aerothermal energy, heat pumps, and biomass are all examples [36]. The subsidy ranges from 40% for

full buildings to 30% for individual residences or businesses, with extra percentages based on energy savings, the social aspect of the activity, or whether it is offered as part of a larger project.

Change of lighting system is the third type. In order to develop more efficient technology. Subsidies range from 5% to 20% for all types of properties, with some variations based on criteria such as consumption savings [37].

4.1.3 Similarities

A discerning analysis reveals compelling threads of similarity within the intricate tapestry of energy-efficient household initiatives across various member states. These shared attributes, observed in the pursuit of promoting energy-conscious domestic environments, serve as foundations for the strategic formulation of motivational schemes. The following consistent patterns emerge, representing a confluence of practices that traverse geographical boundaries:

- Promotion of Energy-Efficient Materials and Installations (schemes to cover the cost and installation of energy-efficient materials)
- Universal Embrace of Primary Residences (primary residence is always covered)
- Facilitation through Low-Interest Loans (low-interest loans can be granted to fund changes)
- Targeted Loan Coverage Percentage (loans granted to cover a specific percentage of costs)
- Holistic Building Envelope Enhancement (funding addresses the upgrade of the building envelope of existing structures (thermal insulation, enhanced lighting, solar panel installation, and more efficient heating, hot water, and cooling systems))
- Socioeconomic Equity through Priority Allocations (low-income households have priority for funding schemes)
- Phasing Out Inefficient Systems (replacement of older systems that may not be energy efficient or may use fossil fuels)

4.1.3.1 Promotion of Energy-Efficient Materials and Installations

A conspicuous trend emerges wherein multiple MSs champion the incorporation of energy-efficient materials within households. The strategic subsidization of installation costs for such materials underscores a concerted effort to incentivize adoption. This cross-border emphasis echoes an industry-wide recognition of these materials' pivotal role in driving sustainable energy practices.

4.1.3.2 Universal Embrace of Primary Residences

Across the spectrum of member states, a resolute commitment to advancing energy efficiency within primary residences is universally evident. This harmonious focus underscores the inherent acknowledgement of homes as primary arenas for impactful energy consumption reduction. It echoes a collective commitment to mitigating carbon footprints at their very source.

4.1.3.3 Facilitation through Low-Interest Loans

An astute strategy pervasive across diverse member states is the provision of low-interest loans as a financial catalyst for energy-efficient transformations. The imparting of such financial incentives not only eases the burden on homeowners but also underscores the state's recognition of the societal significance of energy-conscious homes.

4.1.3.4 Targeted Loan Coverage Percentage

A noteworthy parallel among MSs lies in structuring loans to cover specific percentages of transformation costs. This measured approach ensures equitable distribution of financial assistance,

resonating with the ethos of fostering inclusive energy efficiency practices across socioeconomic strata.

4.1.3.5 Holistic Building Envelope Enhancement

Conspicuously, the emphasis extends beyond isolated measures, encapsulating a holistic approach toward building enhancement. Investments are channeled toward enhancing the building envelope through initiatives encompassing thermal insulation, advanced lighting systems, solar panel integration, and optimized heating, cooling, and hot water systems. This integrative perspective underscores the holistic transformation of homes into energy-efficient havens.

4.1.3.6 Socioeconomic Equity through Priority Allocations

An equitable sentiment echoes through the prioritization of low-income households for funding schemes. This collective emphasis transcends geopolitical boundaries, reflecting a shared commitment to addressing socioeconomic disparities by facilitating access to energy-efficient advancements for all strata of society.

4.1.3.7 Phasing Out Inefficient Systems

An overt convergence among MSs is witnessed in the consensus to phase out archaic, inefficient systems reliant on fossil fuels. This collective stance underscores the profound paradigm shift underway—a shift toward systems aligned with sustainability imperatives.

In conclusion, the observance of these commonalities transcends the borders of member states, painting a vivid picture of shared objectives and strategies within the realm of energy-efficient households. These overarching patterns stand as a testament to a united commitment to fostering conscious energy use. Moreover, they lay a robust foundation for the formulation of motivational schemes that not only build upon successful practices but also inject innovation, driving the building sector toward a sustainable future.

4.1.4 Differences

Within the complex expanse of MSs comprising the EU, a tapestry of distinctions in funding allocations and eligibility prerequisites for energy-efficient initiatives has come to the fore. This intricate interplay of divergent approaches illuminates a spectrum of dynamics, encapsulating both financial nuances and conditional intricacies that shape the energy-conscious landscape. Exploring these disparities reveals a mosaic of considerations, embodying both financial magnitudes and the contextual intricacies underpinning the efficacy of these funding mechanisms.

The manifest dissimilarities spanning the gamut of member states underscore not only variances in the quantum of funding allocations but also the confluence of conditions that engender eligibility for these funding paradigms. It is within this juxtaposition of disparities that a myriad of insights emerge:

- Buildings that are eligible for funding have different construction years – (built in 2007 or older versus buildings that are at least two years old)
- Funding schemes are from the energy provider companies rather than the government (France)
- In Germany, the individuals applying for funding do not have to be citizens
- Different sums are covered in different countries as well as different regions within the countries
- Funding is only given if minimum energy efficiency is proven based on the changes that are made in the renovation

- Some countries require a minimum EPC level C for funding to be granted, while others do not have this requirement
- Support is provided via low-interest-rate loans as well as lump sums from the government.
- Secondary residences are eligible for funding in some countries
- Some countries allow for multiple schemes to be combined for one property, whereas in other countries, they do not permit this – only one scheme can be used.

4.1.4.1 Heterogeneous Building Eligibility

The eligibility criteria for availing funding for energy-efficient projects hinge upon a heterogeneous range of factors. A salient divergence lies in the stipulated age of buildings deemed eligible for such incentives. The temporal spectrum spans from structures erected in 2007 or earlier to buildings that have matured into at least a two-year existence. This discrepancy, emblematic of diverse governmental perspectives, reflects the manifold trajectories adopted by member states.

4.1.4.2 Origins of Funding Schemes

A pivotal distinction arises in the genesis of funding schemes. While numerous countries tether these incentives to energy provider companies, a conspicuous outlier is France, where the impetus emanates from entities outside the governmental sphere. This variance underscores the multifaceted origins of funding initiatives, offering a panoramic perspective on the orchestrators of energy-efficient empowerment.

4.1.4.3 Residence of Beneficiaries

The residency status of beneficiaries further delineates the contours of eligibility. The eligibility landscape extends beyond the confines of citizenship in Germany, where applicants seeking funding need not necessarily be citizens. This inclination towards inclusivity offers a paradigm shift in the demographic dynamics of beneficiaries, fostering broader participation.

4.1.4.4 Heterogeneous Funding Magnitudes

Financial dimensions exhibit significant variations, encompassing both national and regional disparities. The spectrum spans divergent funding magnitudes disbursed across countries and, intriguingly, within disparate regions of a singular nation. This intricate calculus underscores the nuanced strategies employed to cater to local needs, balancing financial distribution with targeted impact.

4.1.4.5 Stringent Efficiency Preconditions

A recurring theme within funding stipulations is the stringent condition necessitating a demonstrable elevation in energy efficiency as a prerequisite for funding acquisition. The imperative to showcase tangible enhancements catalyzed by renovation activities forms a common thread, underlining the emphasis on substantive impact as a determinant for financial endorsement.

4.1.4.6 Minimum Energy Performance Requirements

Conceptions of energy efficiency are further accentuated by disparities in minimum Energy Performance Certificate (EPC) levels. The prerequisite of achieving EPC level C for funding acquisition emerges as a distinctive criterion within certain member states, while others navigate this terrain unencumbered by such prerequisites.

4.1.4.7 Assortment of Support Mechanisms

The repertoire of support mechanisms is wide-ranging, encompassing an array of avenues, including low-interest rate loans and government-provided lump-sum disbursements. This diversity underscores the nuanced orchestration of financial mechanisms to cater to an array of financial profiles and needs.

4.1.4.8 Scope of Eligibility

Distinctive member states offer a distinctive breadth of eligibility, encompassing not solely primary residences but extending the mantle of funding to secondary residences. This variance in scope amplifies the inclusive tenor of certain policies, acknowledging the diverse spectrum of residential patterns.

4.1.4.9 Combination of Schemes

An intriguing divergence is manifest in the accommodation of multiple schemes for a single property. While certain countries embrace the amalgamation of multiple schemes, others adhere to the strictures of permitting only a solitary scheme per property. This disparity crystallizes the contrasting perspectives on the synergy of multiple funding paradigms.

The heterogeneous fabric of disparities across MSs casts an illuminating spotlight on the manifold pathways undertaken to invigorate energy-efficient paradigms. These disparities mirror the intricate interplay between fiscal considerations, policy formulations, and socio-contextual dynamics. Within this mixture of distinctions, the blueprint for the D^2EPC consortium's motivational schemes seeks to harmoniously integrate the transformative potential of disparate perspectives into a cohesive and impactful energy-conscious framework.

4.2 Emission Trading Scheme

The European Union's Emission Trading Scheme (EU ETS) is the current policy implemented by the EU in their efforts to combat climate change via the reduction of greenhouse gas emissions in a cost-effective manner [38]. The EU ETS is considered the world's first major carbon market, and it remains one of the biggest ones in the world.

The EU ETS is based on the 'cap and trade' principle where a limit, a cap, is allocated on how many greenhouse gases can be emitted by heavily polluting industries within a year. Based on the industry cap, a maximum limit of emissions is allocated for each operator within each heavily polluting industry. Each operator is expected to stay within their allocated emissions cap, and if they fail to do so, they will incur financial penalties [39]. This touches on the principle of 'polluter pays' where for each unit of excess pollution that is contributed into the world, a financial cost is associated with it and thus has to be paid back – more pollution, higher fines. If the polluter fails to pay the appropriate fine and the cost of the pollution is absorbed by society, then it is considered a market failure in economic terms. Heavily polluting operators that cannot stay within their allocated emissions cap have two options in order to address the excess pollution that they have emitted. Operators either pay a fine, based on the global carbon price, or they are able to buy unused emissions from less polluting operators that were able to stay within their own cap/limit [40]. This purchase of allowances from less polluting operators is permitted as the yearly cap of emissions for the industry, as a whole, is within the limits that were set at the start of the year by the EU.

Subsequently, organizations that manage to stay within their carbon emission limits/caps can choose to keep their unused carbon emissions for the following year, or they can choose to sell them to organizations that did not stay within their cap and polluted to a greater extent.

The cap and trade scheme was revised on multiple occasions to keep up with the demands and needs of the EU. Revisions were conducted in 4 different phases, with the end goal being the successful implementation of carbon neutrality for the EU by 2050.

4.2.1 Initial steps

In 1997, during the Kyoto Protocol, 37 countries were identified as extreme polluters, where, for the first time, it was agreed, via legally binding legislation, the need to reduce emissions. Subsequently, instruments were identified as being needed in order for the reductions to be made possible in reaching these targets [41]. In March 2000, the first draft of the EU ETS was introduced via a green paper, where stakeholders were consulted to help develop a useful scheme, and in 2003, the EU ETS Directive was adopted, which allowed for the successful implementation of the system in 2005.

4.2.1.1 Phase 1

The first phase of the EU ETS, between 2005 and 2007, was considered the pilot stage where the principle of 'learning by doing' was introduced. This was seen as a preparatory stage so as to have a good understanding prior to the introduction of phase 2, which would ultimately address the targets set by the Kyoto Protocol.

Key takeaways:

- Addressed CO_2 emissions from power generators and energy-intensive industries only
- Almost all allowances were given to businesses for free
- Penalty for non-compliance was set at 40 euro per tonne
- The carbon price was established
- Free trade of emissions in the EU
- The infrastructure needed to monitor, report, and verify emissions from the businesses covered

During phase 1, there was a lack of emissions data; hence, the caps that were allocated were done based on an estimate, resulting in the total amount of allowances exceeding the emissions, and in 2007, the price for set allowances was dropped to zero – resulting in a need to readjust the caps that were allocated. Supply was greater than demand, thus driving the price down to zero.

Although allowances, in the current EU ETS, are permitted to be transferred, the allowances were not permitted to be transferred between phase 1 and phase 2 due to the excessive amount of surplus allowances in phase 1. Phase 1 was considered the trial period where mistakes were made and adjusted so that phase 2 would reflect the true intentions of the EU ETS.

4.2.1.2 Phase 2

Phase 2, 2008 - 2012, which coincided with the first official commitment period of the Kyoto Protocol, where countries had set goals to meet in reducing their emissions, had the following takeaways:

- Lower cap allowances (compared to phase 1)
- Three (3) more countries joined, making the list of polluting countries a total of 40
- Nitrous oxide emissions were included in some country emission allowances
- Free allocation of emissions fell to 90%
- Some countries held auctions for their allowances
- Non-compliance penalty was raised to 100 euros per tonne

- Businesses were permitted to purchase international credits – an equivalent of 1.4 billion tonnes of CO2
- The aviation sector was included in January 2012, but flights to and from non-EU countries were suspended for 2012

Emissions were based on the verified emissions from Phase 1; thus, the emissions were lowered in phase 2. During the 2008 economic crisis, the reduced emissions were greater than what was expected, thus resulting in a surplus of allowances, which affected the carbon price considerably – a disturbance due to the change in supply and demand.

4.2.1.3 Phase 3

Phase 3, 2013-2020, changed considerably compared to the previous phases. The main changes included:

- EU-wide cap rather than nationwide cap
- No free allocation of emission caps; auctioning was used as the default method
- Harmonized allocation rules applying to the allowances still given away for free
- More sectors and more gases are included
- 300 million allowances were set aside for the New Entrants Reserve (NER) to fund the deployment of innovative, renewable energy technologies and carbon capture and storage through the NER 300 program

4.2.1.4 Phase 4

Phase 4 is the longest phase, expected to last between 2021 and 2030. Phase 4 of the EU ETS has been revised to reflect the changes in legislation so as for the EU to reach its goal of carbon neutrality by 2050. The expected changes for phase 4 include:

- Decrease in annual allowances by 2.2%, per annum, compared to the current rate of 1.74%
- Reinforcement of the Market Stability Reserve (MSR) – the mechanism created and enforced by the EU to reduce surplus emission allowances in the carbon market as well as to improve the resilience of the EU ETS' resilience to future shocks
- In an effort to improve the functioning of the EU ETS, from 2023 onwards, the number of allowances held in reserve will be limited to the auction volume of the previous year – holdings above this will lose their validity.

Auctioning is used within the EU ETS as it is considered the most transparent method for allocating emission allowances and puts into practice the principle of ‘polluter pays'. Through auctioning, 57 billion euros were raised for the time period 2012-2020, where 78% of the revenues have been reinvested for climate and energy research-related purposes. The ETS not only applies pressure on heavily polluting industries, but it also raises money that is then reinvested within the research and development industry of energy and climate change.

Yearly reductions in emissions, via the EU ETS, force heavy polluting operators to make changes so that they can stay within the limits set for them for the year. As a result, operators start with the most cost-effective changes they can make – cheap changes that reduce the most carbon emissions. This, combined with the investment in research and development, pushed the industries to make worthwhile changes to reduce emissions.

Having a unified understanding and implementation of the cap and trade scheme for the ETS on a global scale prevents heavy polluters from moving their business abroad and polluting in regions that

they will not be held accountable or in regions with lower fines that they can afford to pay. Global prices of carbon, in combination with stringent laws regarding the implementation of the ETS caps, ensure that polluters pay, and it discourages the relocation of heavily polluting businesses abroad.

4.3 Carbon prices

Carbon pricing is a tool that has been used to allocate a price per tonne of carbon being emitted into the atmosphere [42]. This price is calculated based on the external cost of the emission on the public – including damage to healthcare, effect on climate change, property loss due to rising sea levels etc. – and ties them to their sources through a price. In doing so, the cost/price of the emission can be shifted to those that have actually caused the damage rather than the general public being affected and no repercussions taking place. The carbon price allows for the 'burden' of the damage that has been caused due to the emission of greenhouse gases to be paid by the one responsible, the polluter. This allows heavy polluters to take the initiative in whether they will change their own practices and reduce their emissions so as to not pay hefty fines or if they will continue to pollute and subsequently pay the appropriate fine that corresponds to their pollution [43]. This is seen as a flexible and least-cost-effective way to implement changes in society.

Setting an appropriate price for greenhouse gas emissions is critical for internalizing the external cost of climate change in the broadest range of economic decision-making and creating economic incentives for clean development. It can help mobilize the financial investments needed to stimulate clean technology and market innovation, thereby fuelling new, low-carbon economic drivers.

According to governments and businesses, Carbon pricing plays an increasingly important role in the transition to a low-carbon economy. Carbon pricing is one of the tools available to governments as part of the climate policy package required to reduce emissions. Most of the time, it is a source of revenue, which is especially important in a financial environment. Internal carbon pricing is used by businesses to assess the impact of mandatory carbon prices on their operations and to identify potential climate risks and revenue opportunities. Finally, long-term investors use carbon pricing to assess the potential impact of climate change policies on their investment portfolios, enabling them to rethink investment strategies and reallocate capital toward low-carbon or climate-resilient activities.

The EU has published real-past carbon prices, as well as projected carbon prices up to 2050. The projected prices have been calculated on two scenarios: one where no additional measures will be implemented (no new schemes will be introduced) and a scenario where additional measures will be implemented. In the scenario of additional measures, the carbon price is expected to be almost 2.5 times more expensive by 2050 compared to the projected price of no additional measures. As the EU has set a goal for reaching carbon neutrality by 2050, it is expected that additional measures need to be implemented in order to reach said goal, thus driving the price of carbon up and making carbon pollution less accessible to polluting industries as well as individuals.

Based on the past, the price of carbon is expected to rise, yet to reach the ultimate goal of carbon neutrality, additional measures must be added to tackle the dire need to reduce carbon emissions. **Table 2** shows the projected price of carbon based on the two scenarios where additional measures will be added or not.

Table 2: Harmonised trajectory for the carbon price/value (EUR2020/tCO2)

EUR 2020/tCO2	**Common trajectory carbon price existing ETS up to 2030 With Additional Measure Trajectory**
2018*	16
2019*	25

2020*	24	
2021*	54	
2022	75	
2023	77	
2024	78	
2025	80***	
2030	80***	
	With Existing Measure Trajectory	**With Additional Measure Trajectory**
2035	82	120**
2040	85	250**
2045	130	360**
2050	160	410**

*2018-2021 data are a yearly average of daily value expressed in current EUR of dated EUX EUA. The conversion from current EUR and EUR2016 to EUR2020 uses the ESTAT HICP index (data extracted in May 2022).

** The indicative post-2030 with additional measures trajectory is a modelling driver to reach the EU 2050 climate neutrality in the FF55 package analysis. It is acknowledged that national analyses projecting economy-wide GHG emissions compatible with the EU 2050 climate neutrality objective may provide a different carbon value trajectory

*** The corresponding carbon prices expressed in nominal values are about 90 and 100EUR/tCO2 for 2025 and 2030, assuming an index of 105/76 in 2020, 118.6 in 2025, and 130.9 in 2030, compared to 100 in 2015.

4.4 Global overview

Addressing climate change and global warming, the focal point of pioneering scientific research rests upon the triad of carbon production, air pollution, and contamination. While early studies predominantly spotlighted heavily polluting industries, a paradigm shift over the past decade has ushered in a transformative perspective that acknowledges the paramount significance of individual carbon footprints. Although the cumulative impact of individual actions on carbon emissions was initially understated, recent years have witnessed a burgeoning recognition of their pivotal role in shaping global warming dynamics.

In a landscape where industries stand as behemoths of carbon emissions, it is easy to dismiss the impact of individual behaviours. However, an imperative realization surfaces upon delving into the heart of demographic expansion. With the current global population surpassing an unprecedented 8 billion, the aggregate carbon footprint of every individual—though seemingly modest—exerts a profound influence on the world's ecological equilibrium and, by extension, on the overarching phenomenon of global warming.

At the nucleus of comprehending individual impact lies the concept of the "carbon footprint." This metric, succinctly defined as the "amount of carbon dioxide (CO_2) emissions associated with all the activities of a person or other entity" [44], unveils the carbon manifestation of individual choices, whether in daily routines or specific actions. In essence, it embodies the amalgamation of carbon dioxide released across diverse actions, thus encapsulating the net effect of an individual's presence within the global carbon cycle.

Evaluating individual contributions to carbon emissions unfurls a tapestry interwoven with intricate variations. These divergences traverse geographical boundaries and transcend the contours of demographic segments within a country. Anticipatedly, the chasm between affluent and less affluent individuals echoes a stark reality—those endowed with greater resources tend to exhibit higher carbon footprints. This pattern resonates universally, transcending regional confines and echoing a disconcerting global norm.

Initiatives, such as the EU Emissions Trading System (EU ETS), have fostered a noteworthy reduction in carbon contribution disparities between countries. Nevertheless, paradoxically, a contrasting narrative has emerged within individual countries. Inequalities in carbon emissions between individuals within the same nation have burgeoned considerably. This phenomenon, ubiquitously prevalent across all global regions, underscores the complex interplay of socioeconomic factors, lifestyle disparities, and access to resources that collectively shape carbon footprints.

Figure 1 stands as a poignant visual encapsulation of the evolving global emissions inequality spanning the years 1990 to 2019 [45]. This graph serves as a poignant reminder that while macro-level initiatives drive progress in inter-country parity, micro-level discrepancies have concurrently escalated, presenting a formidable challenge to equitable emissions reduction strategies.

In the grand tapestry of combating climate change, every thread counts. Acknowledging and rectifying the inequalities within individual carbon contributions is imperative to fostering a sustainable future. As industries and nations strive to align with global emissions reduction goals, harnessing the collective power of individual actions holds the potential to herald a transformative shift. These global efforts and individual consciousness will undoubtedly forge a path toward mitigating the impacts of global warming and securing the welfare of our planet for generations to come.

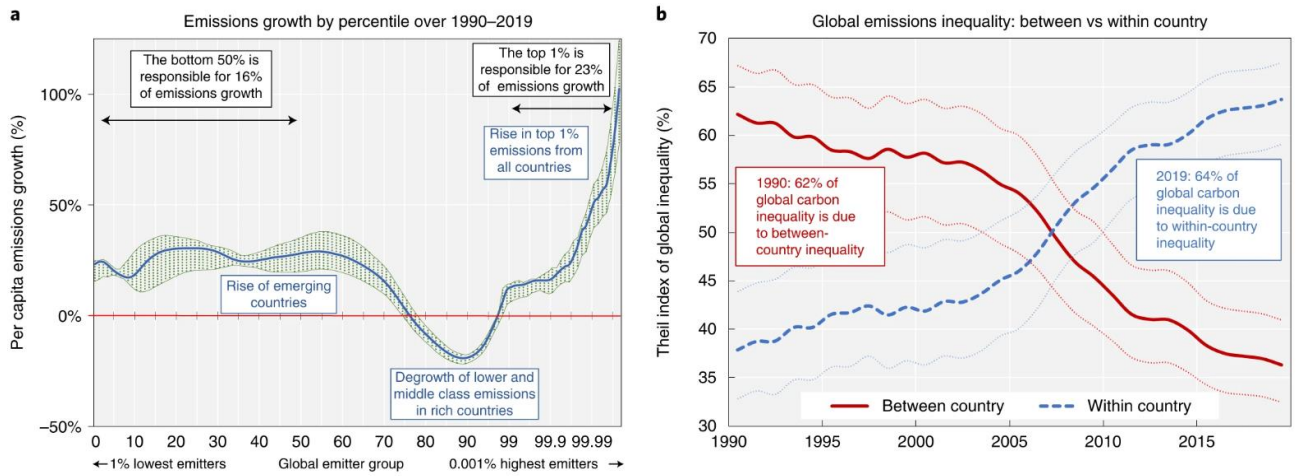

Figure 1: Global emissions inequality over 1990-2019 [45]

The dynamic interplay between emissions growth and its distribution across percentiles offers a compelling narrative, as depicted in Figure 1a. Spanning the temporal arc from 1990 to 2019, this visual representation illuminates a shifting trajectory. Notably, emissions growth is not a uniform phenomenon; it adheres to a distribution that diverges across percentiles. This nuanced view underscores the need for targeted interventions, a stance that underpins the motivations of projects such as D2EPC.

Figure 1b intricately weaves the story of global carbon inequality, casting its spotlight both on disparities between nations and within nations themselves. In this visual narrative spanning the years 1990 to 2019, discernible patterns emerge. In 1990, a substantial proportion of global carbon inequality—62% to be precise—was attributed to inter-country disparities. However, the landscape

shifted notably by 2019, with a remarkable 64% of global carbon inequality arising from within-country discrepancies. This transformation carries profound implications, signifying a discernible shift from inter-country pollution inequality to a rising emphasis on addressing inequities within national boundaries.

A pivotal revelation surfaces from these visual narratives—a discernible change in the dynamics of polluters. Historically, the locus of concern centred around disparities between nations, gradually evolving to spotlight imbalances within nations. Initiatives, including the innovative undertakings of the D2EPC project and global frameworks like the Emissions Trading System (ETS) and universal carbon pricing, emerge as beacons of change in response to this transition.

4.4.1 Motivational Paradigms

At the core of these initiatives lies the concept of motivation through consequence. Such schemes serve as transformative motivators, compelling heavy polluters to transition towards environmentally responsible practices. Rather than migrating polluting activities to regions where environmental regulations are lenient or lower carbon pricing, these initiatives prompt a shift towards ecologically conscientious practices. This evolution encapsulates a paradigmatic shift—polluters are incentivized to align their actions with sustainable ideals rather than evading accountability through geographic displacement.

- Global ETS and Universal Carbon Pricing: Addressing Disparity and Responsibility

Central to the strategy of addressing both local and global pollution concerns are mechanisms such as the global ETS and international carbon pricing. These frameworks resonate with the "polluter pays" principle, wherein entities responsible for pollution are held financially accountable for the ecological repercussions of their actions. The crux of this approach lies in curbing the propensity of polluters to externalize costs or engage in geographical arbitrage.

- Beyond Boundaries: Collaborative Action and Global Impact

While the "not in my backyard, not my problem" mindset has historically been pervasive, contemporary societal attitudes are evolving. Robust legislation is emerging to counteract this sentiment. Increasingly, international collaborations are coming to the fore—unifying efforts to address pollution's toll within affected areas and across a global canvas. As the interconnectedness of carbon emissions and their impact on global warming becomes undeniable, a collective responsibility is taking root, transcending local boundaries and resonating on a planetary scale.

- A Barrier Against Pollution: A Global Shield for Responsible Progress

The introduction of global frameworks, notably the ETS and international carbon pricing, erects an ethical and operational barrier against the proliferation of heavy polluters. As the canvas of change extends beyond national borders, these initiatives stand as vanguards, guarding against the perpetuation of practices that exploit regulatory disparities. By holding the mirror of accountability to each entity, these frameworks inspire responsible action, catalyzing a harmonious equilibrium between economic pursuits and environmental stewardship.

5 Development of the proposed scheme

The motivational schemes for conscious energy users in the building sector will be heavily based on how the EU ETS is structured and how it acts as a financial driver/motivator for heavily polluting operators in heavily polluting industries, as a means for lowering carbon emission over time. The motivational schemes will be separated into both awards schemes as well as penalty schemes, acting as the 'stick and carrot' analogy. Effort and successful implementation of changes will be awarded, and failure to do so will be penalized accordingly.

Both the award schemes as well as the penalty schemes that are being proposed in the scope of this project will be based on the global price of carbon. The global price of carbon is expected to increase over the years, reaching a projected price of 410 euros per ton of carbon by 2050 (with additional measures), as the EU has set a goal of becoming carbon neutral by then. The demand and supply will help drive the price to almost three (3) times the price of what it is currently at. This drastic increase in the price of carbon will act as a strong motive for households to stay within their allocated household energy allowances so as to receive compensation for abiding by the new legislation rather than having to pay hefty fines.

5.1 Motivational Awards Scheme

In the context of propelling a paradigm shift towards energy-efficient practices within households, the project D^2EPC lays forth a strategic framework encompassing four distinct award schemes. These devised schemes wield the potential to galvanize substantial reductions in energy consumption, thereby fostering a culture of conscious energy usage among households. The four proposed award schemes are:

- Tax Reductions
- Reduced Electricity Bill
- Cash Back
- Credit Transfer
- Common Pricing Principle and Customized Choice

Central to the ethos of these award schemes is their unified foundation upon a singular pricing principle. This pioneering approach underscores the adaptability and inclusivity of the proposed schemes, ensuring that households possess the autonomy to elect a scheme aligning with their preferences and aspirations. A noteworthy facet pertains to the provision of annual flexibility, granting households the prerogative to seamlessly transition from one scheme to another, thus tailoring their energy conservation strategy in accordance with evolving circumstances.

The pivotal facet anchoring these award schemes is their pricing architecture, intricately linked to the global panorama of carbon pricing. Inextricably tied to the international carbon market, the pricing of these schemes is irrefutably tethered to the pressing need for carbon emission reduction. This resonates profoundly with the overarching objectives of the European Union, which ardently aspires to attain carbon neutrality by the year 2050. A key tenet in this pursuit is the deliberate curtailment of carbon allowances, a quintessential facet of the EU Emission Trading System (ETS). This strategic reduction imparts an upward impetus to carbon prices, akin to the dynamics of demand and supply.

The synergy between these award schemes and global carbon pricing is of paramount significance. Envision a scenario where households, through judicious energy consumption, remain within their allocated carbon quotas. In this scenario, the escalating trajectory of carbon prices translates into tangible benefits for conscientious households. Financial incentives commensurate with their energy-efficient practices amplify their motivation to conform to their allocated energy bounds. Forecasts hint

at an upswing in carbon pricing, projected to culminate in a zenith of 410 euros per tonne by 2050, catalyzed by supplementary measures augmenting extant initiatives.

Acknowledging the nuanced predilections of diverse governments and member states, an element of customization is contemplated. Some jurisdictions might opt for a marginally divergent pricing structure, albeit within bounds that uphold the fundamental underpinning principle. This flexible latitude seeks to harmonize award schemes with regional variances while upholding the overarching objective of incentivizing energy-conscious behavior.

A further layer of sophistication is infused into the design by embracing differential pricing for surplus units of energy (kWh). This strategic maneuver empowers governments to calibrate the funds directed back into households finely. This control mechanism serves as a strategic instrument to wield influence over energy consumption patterns, thereby steering households toward optimal energy efficiency.

In summary, the architectural blueprint of the motivational award schemes, meticulously outlined by the project D^2EPC, weaves a tapestry of possibilities that synergistically intertwine global carbon dynamics with localized motivations. The envisioned confluence of global sustainability imperatives and household-centric awards is poised to be a transformative force, fostering a collective movement towards sustainable energy practices within households.

5.1.1 Tax reductions

The strategic integration of tax reduction mechanisms assumes a pivotal role in fostering conscious energy usage and engendering a paradigm shift towards sustainable practices. This discerning approach represents an innovative and pragmatic method of motivating households within MSs to adopt energy-efficient practices while simultaneously alleviating their substantial tax burden. This section delves into the profound potential of tax reduction as a powerful award scheme, aligning individual interests with overarching environmental goals.

Tax reduction, hinging upon the energy consumption patterns of households, emerges as a compelling and multifaceted incentive mechanism. Notably, households across diverse member states bear the weight of considerable tax obligations. Thus, a paradigm wherein households not only garner economic benefits from curbing their energy consumption but also evade tax liabilities becomes a potent impetus for transformation.

In this context, the allure of tax reduction is not confined solely to monetary gain. It transcends into a realm where fiscal responsibility converges with ecological consciousness. The motivation to minimize energy consumption not only translates into immediate financial savings but also extends to a broader ambition of carbon emission reduction. The monetary equivalent of unutilized or unemitted carbon emissions is seamlessly subtracted from the household's tax liabilities through an ingenious mechanism.

In the majority of member states, the weight of taxation on households is palpable. The financial load imposed by taxes is a tangible burden that resonates across socio-economic strata. Governments, acutely aware of this fiscal strain, possess the unique prerogative to extend a lifeline in the form of tax reductions. Such concessions resonate as a beacon of relief, entwining financial well-being with environmental stewardship.

Within this framework, tax reduction materializes as an astute strategy for governments to wield their influence in steering households towards energy-efficient behavior. The allure of lighter tax liabilities cascades into an embodied incentive that emboldens households to remain within the prescribed energy consumption threshold. This, in essence, enforces a symbiotic relationship between energy consciousness and financial pragmatism.

The dynamicity of tax reduction schemes is underscored by their adaptability to the nuanced context of each member state's economy and financial landscape. Governments possess the autonomy to calibrate which taxes are encompassed within this scheme meticulously. Such flexibility allows for alignment with diverse economic realities, extending the feasibility of implementation from the national level to the intricacies of local councils.

In conclusion, the integration of tax reduction as a motivational scheme within conscious energy usage initiatives represents a harmonious convergence of fiscal and environmental prudence. Governments assume the mantle of catalytic agents of change by alleviating the onerous tax burdens carried by households and concurrently nurturing a collective commitment to energy efficiency. This innovative mechanism reshapes the energy consumption narrative, fostering a symbiotic relationship between economic interests and sustainable aspirations. In the tapestry of strategies for conscious energy consumption, tax reduction stands as a beacon of transformative potential, poised to illuminate the path toward a greener future.

5.1.2 Reduced electricity bills

Within the paradigm of fostering energy efficiency, a series of pioneering strategies are poised to revolutionize the landscape. These strategies draw inspiration from the established successes of Energy Services Companies (ESCOs), renowned for their ability to usher in reduced energy expenditures. By harnessing the principles that underscore the operations of ESCOs, a transformative framework is poised to offer substantial financial relief to conscientious energy users within the building sector.

The bedrock of this innovative approach rests on emulating the modus operandi of ESCOs. At the heart of ESCOs' operational philosophy lies their commitment to guaranteeing energy savings, complemented by maintaining the same standard of energy services, albeit at significantly diminished costs in comparison to conventional energy providers. This is realized through meticulously structured energy cost savings contracts, encompassing maintenance, operational aspects, and utility budget allocation. Furthermore, ESCOs, in their role as project stewards, extend their purview to encompass design, financing, installation, and ongoing management within the domain of buildings.

The symbiotic partnership between building proprietors and ESCOs stands as a cornerstone of this visionary approach. Especially pertinent in situations where building proprietors grapple with resource constraints for the adoption of energy-efficient technologies, ESCOs emerge as catalysts for change. Within this dynamic, ESCOs step forward to absorb the capital expenditure associated with technology upgrades while concurrently committing to the perpetual maintenance of these technologies. In return, building owners commit to a structured monthly or yearly fee, encapsulating the comprehensive suite of services rendered by ESCOs.

The central premise of this innovative arrangement resonates with economic prudence. Building owners are poised to reap substantial benefits by opting for ESCO engagement. This is underscored by the undeniable financial allure that ESCO-operated energy management affords. The remittance to ESCOs, in the form of monthly payments, is strategically designed to be significantly more economical than the conventional monthly electricity bill. This engenders a landscape where fiscal savings align harmoniously with conscientious energy consumption—a compelling proposition for building proprietors seeking fiscal prudence.

As the pursuit of energy efficiency extends its reach, households stand to gain from an innovative mechanism that synthesizes financial incentives and environmental stewardship. The strategy involves the conversion of surplus energy allowances—accrued over a fiscal year—into tangible monetary values. This monetization is intricately linked to the prevailing international carbon price, imbuing it

with a robust foundation. The resultant monetized values, akin to credits, find their purpose in offsetting energy expenditures in the upcoming fiscal cycle.

This approach further resonates with households already endowed with energy-efficient installations. These households, already relishing reduced energy expenditures, find this scheme to be an avenue for augmenting their financial gains. The symbiosis between energy-efficient practices and monetary rewards forms a compelling incentive, propelling households toward adopting even more sophisticated energy-saving technologies.

In conclusion, these innovative strategies represent a paradigm shift within the arena of conscious energy consumption. By capitalizing on ESCO dynamics, a potent avenue for reduced energy expenditures emerges, fostering a landscape where financial prudence and sustainable practices harmonize seamlessly. Simultaneously, the concept of monetizing energy surpluses stands as a testament to the ingenious fusion of fiscal benefits and environmental stewardship, ultimately resulting in a more energy-efficient and sustainable future.

5.1.3 Cashback

Within the comprehensive framework of devising motivational schemes, a distinctive proposition comes forth in the form of a pioneering "Cashback Scheme." Drawing inspiration from the fundamental tenets that underpin the existing award schemes, this novel approach is deeply rooted in the internationally recognized principles governing carbon pricing. A seamless extension of the project's overarching goals, this Cashback Scheme emerges as an innovative and inclusive avenue to incentivize conscientious energy practices within the building sector.

Central to the design of the Cashback Scheme is the strategic alignment of pricing principles with those that substantiate renowned award schemes. As established through international carbon pricing norms, the intrinsic value of carbon emissions reduction is distinctly quantified. By mirroring this valuation, the Cashback Scheme leverages the same pricing bedrock to translate energy-efficient behaviour into tangible monetary benefits. This emulation ensures a harmonious integration with the existing award systems, fostering a cohesive ecosystem of incentives for energy users.

A distinctive hallmark of the Cashback Scheme lies in its universality, offering an attractive proposition to households across diverse economic strata. The unmitigated utility of cash, free from constraints, underscores its allure. Unlike certain incentives confined to specific utility domains, this scheme emancipates beneficiaries, empowering them to allocate the cash windfall according to their discretion. This flexibility resonates profoundly with a spectrum of energy users, forging an inclusive approach that transcends economic divisions.

In essence, the Cashback Scheme emerges as a beacon of equitable motivation. Particularly resonant for low-income households, this scheme transcends mere energy-related expenditures. It emboldens individuals to channel the monetary influx towards a multitude of essential needs, ranging from educational aspirations to healthcare exigencies. This multi-dimensional empowerment breathes life into the scheme, fostering resonance and receptivity among demographics that might have previously been marginalized in the discourse of energy incentives.

The ethos of the Cashback Scheme encapsulates an empowerment ethos driven by the dynamics of choice. This empowerment not only amplifies the value proposition of energy-conscious behaviour but also redefines the narrative of sustainability within the socio-economic landscape. By situating individuals as architects of their own choices, the scheme transcends the transactional, metamorphosing into a catalyst for holistic well-being.

In conclusion, the inception of the Cashback Scheme advances a new paradigm in the realm of motivational schemes for conscientious energy users within the building sector. As an intricate mosaic

of established carbon pricing principles and socio-economic empowerment, this innovative scheme emerges as a unifying force, binding diverse energy users under the banner of sustainability. It epitomizes a visionary stride towards holistic incentivization, infusing the conscious energy landscape with an infusion of choice, empowerment, and economic well-being. This emblematic endeavour paves the way for a transformational shift—one where sustainability converges harmoniously with the multifaceted aspirations of individuals and households.

5.1.4 Credit transfer

A multifaceted strategy has been devised to maximize the adaptability and efficacy of energy consumption policies. This strategy encapsulates the notion of allowing households the prerogative to transform their surplus or unused energy allowances into transferable credits viable for utilization in subsequent years. This innovative approach introduces a layer of flexibility and resilience into the energy consumption framework, catering to modern households' evolving dynamics and fluid nature.

In a dynamic and ever-evolving societal landscape, household dynamics can undergo notable shifts due to myriad factors. For instance, households may experience transformations driven by circumstances such as children leaving home for studies abroad, transitions arising from parental divorce, or individuals facing intermittent employment patterns. These scenarios inherently engender fluctuations in energy requirements, often deviating from the confines of predefined yearly allowances.

The proposed mechanism of converting surplus energy allowances into transferable credits effectively addresses this variability in household dynamics. This adaptive flexibility recognizes that rigid annual allocations might not accurately mirror the energy consumption patterns of households experiencing significant transitions. By permitting the conversion of excess allowances into credits, households are endowed with a safety net that caters to unforeseen spikes in energy demands, providing a cushion during 'emergency' situations.

The concept resonates particularly well with households bestowed with limited energy allowances yet susceptible to unpredictable scenarios necessitating heightened energy usage. This provision not only serves as a pragmatic solution but also fosters peace of mind for such households, assuaging concerns related to potential energy shortages during critical junctures.

A judicious framework underpins the transition of energy allowances into transferable credits. These convertible credits are suggested to possess a 'shelf life' extending up to three years. This temporal horizon aligns with both short-term fluctuations and slightly longer-term changes within household dynamics. The three-year window ensures that households are equipped to navigate varying circumstances, striking a balance between immediate exigencies and more sustained adjustments.

In conclusion, the proposal to enhance energy allowance flexibility by enabling households to convert surplus allowances into transferable credits marks a paradigm shift in energy consumption policy. This innovative approach mirrors the dynamism inherent in modern households and caters to their unique exigencies. By extending the utility of energy allowances over time and permitting their strategic deployment during transitional phases, this approach demonstrates a profound commitment to efficacious and responsive energy management. The integration of such a mechanism augments energy resilience and bolsters households' intrinsic adaptability in the face of change.

5.1.5 Contextualized Pricing Paradigm

In the intricately woven fabric of devising motivational schemes that resonate with local communities, an indispensable facet emerges the articulation of pricing structures that reflect not only financial prudence but also align with the pulse of the populace. With a discerning eye toward enhancing user

engagement and fostering the adoption of conscientious energy practices, the D2EPC project deftly navigates the nuanced terrain of pricing strategies.

Central to this strategic pricing calculus is the pivotal parameter of the annual average carbon price—a cornerstone variable that underpins the entire edifice. It is judiciously recommended that the determination of prices for the motivation-awards schemes be intrinsically linked to the prevailing average carbon price for the specific evaluation year. This dynamic linkage lends a measure of flexibility and sensitivity, wherein the financial incentive structure attunes itself to the shifting tides of the carbon market.

The beauty of this pricing paradigm lies in its adaptability to the unique contours of individual member states. Each state possesses the latitude to deliberate and decide upon the pricing spectrum that best befits its socioeconomic tapestry. By doing so, member states assume the role of architects, moulding motivational schemes to resonate harmoniously with their citizenry's aspirations and financial inclinations.

A striking aspect that emerges from this orchestration of motivational pricing is the liberty afforded to member states opting to implement multiple awards schemes. Within this realm of choice, states are empowered to set distinct prices for each individual award. This innovative approach acknowledges the multifaceted nature of incentives and the multifarious motivations that underscore diverse consumer behaviours.

This deliberate diversification of pricing engenders a duality of intent. Member states can opt for the most felicitous pricing strategy—one that reverberates most harmoniously with the aspirations of their residents, engendering a genuine sense of value and incentive. Conversely, there is the pragmatic consideration of governmental financial viability. With the prerogative to select a pricing configuration that dovetails with fiscal realities, states forge a path that is not merely environmentally astute but also judicious from an administrative standpoint.

Consider an illustrative scenario wherein the average carbon price for the year 2021 is appraised at 54 euros per ton of CO_2. This foundational parameter then sets the stage for divergent pricing across distinct awards, exemplifying the ethos of choice and adaptability:

- Tax Reduction: A compelling avenue for incentivizing conscious energy practices, potentially priced at 40 euros per ton of CO_2
- Reduced Electricity Bill: A resonant measure designed to entice with a price tag of 30 euros per ton of CO_2
- Cash Back: A tangible reward, fostering engagement, and potentially pegged at 20 euros per ton of CO_2

In the symphony of developing motivational schemes for conscious energy users, pricing emerges as a harmonious note, orchestrating engagement and transformation. The fluidity of pricing, entwined with the cadence of local preferences and fiscal considerations, heralds an era of incentive systems that are both meaningful and pragmatic. This confluence of purpose and viability, underpinned by dynamic pricing structures, not only bolsters the allure of the motivational schemes but ushers forth a transformative wave of energy consciousness within the building sector.

5.2 Financial Incentives and Penalty Mechanisms

In catalyzing societal shifts toward conscious energy consumption, the potency of financial incentives and penalty mechanisms has been substantiated through multifarious lenses. The EU Emissions Trading System (EU ETS) serves as a poignant exemplar, showcasing how financial motivations can be the fulcrum driving transformative changes within society. Notably, the proposed award schemes

within the ambit of the present project dovetail seamlessly with this paradigm, amplifying the efficacy of financial drivers in inducing positive behaviours.

It is unequivocal that hefty fines, resolute and inescapable, stand as the preeminent 'stick' within the proverbial 'carrot and stick' approach. The interplay between these two facets orchestrates a resonant orchestration of behavioural transformation within societies. Unmistakably, financial motivations, when deftly calibrated, wield exponential efficacy, eclipsing other proposed paradigms.

Aligned with these principles, the penalty scheme meticulously crafted within the annals of the D2EPC project adheres to the same bedrock principle as its award counterpart. This principle rests on the foundational tenets of proportionality and accountability, tethered to the overarching 'polluter pays' ethos. The crux of the penalty scheme is tethered to household consumption of excess energy, invoking a structured and equitable mechanism to balance energy utilization against permissible thresholds.

Intricately, the underpinning philosophy necessitates individual household energy allowances, a calculus of complex considerations outlined in Section '5.3 Thoughts and Considerations'. The calibration of these allowances is quintessential, harmonizing personalized needs with the overarching imperatives of sustainability.

Once these yearly energy allowances are allocated, households assume an obligational mantle of maintaining consumption beneath their designated thresholds, thus sidestepping punitive actions. In instances where excess energy utilization is registered, surmounting the designated limit, the penalty system unfurls. Echoing the 'polluter pays' doctrine, fines are calculated, reflective of both the quantum of excess energy consumed and the consequential carbon footprint engendered.

An intricate calculus is invoked for every unit of surplus energy to gauge the resultant carbon emissions. Anchored within this calculus is the prevailing global average carbon price, an indispensable benchmark against which fines are calibrated. This confluence of variables establishes a principled and data-driven mechanism wherein fines are intrinsically linked to the genuine environmental cost incurred. Critically, the fines are administered annually, a mechanism designed to accommodate the temporal variability inherent within energy consumption patterns. This approach engenders a balanced perspective, accounting for seasonality and aberrant consumption spikes or troughs that might transpire across different months.

In conclusion, the financial tapestry woven within the D^2EPC project seamlessly aligns with the EU ETS paradigm and other globally acknowledged successes. The robustness of this approach resides in its fusion of financial incentives and penalties, steering societal behaviour toward conscientious energy use. Through calibrated financial motivations, fortified by rigorous data analysis and global benchmarks, the project's visionary schemes hold the potential to sculpt a greener, more sustainable energy landscape.

For better clarity, an example is displayed in **Table 3**.

Table 3: Example of penalty scheme being implemented for an average household in 2021

Metric	**Value**
Average carbon price for 2021:	54Euro / tCO_2
Threshold of energy consumption for household A for 2021	3,500 kWh
Actual energy consumption for household A for 2021	4,500kWh
Excess energy consumption for household A for 2021	1,000 kWh
Excess carbon produced for household A for 2021	1,100kgCO_2 = 1.1tCO_2
Fine for household A for 2021	54euro/tCO_2 * 1.1tCO_2 = 59.4 euro

In the given example, the penalty scheme is exemplified through the scenario of an average household (Household A) during the year 2021. The average carbon price for that year stands at 54 Euro per metric ton of CO2 (tCO_2).

- Threshold of Energy Consumption: The predefined energy consumption threshold for Household A for the year 2021 is 3,500 kWh.
- Actual Energy Consumption: Household A's actual energy consumption for the year 2021 amounts to 4,500 kWh.
- Excess Energy Consumption: This denotes the difference between actual energy consumption and the threshold, which for Household A is 1,000 kWh.
- Excess Carbon Produced: This is calculated based on the excess energy consumption, taking into account the carbon intensity associated with energy production. For Household A, it amounts to 1,100 $kgCO_2$, equivalent to 1.1 tCO2.
- Fine Calculation: The fine imposed on Household A is determined by multiplying the excess carbon produced (in tCO2) by the average carbon price for 2021. In this case, the fine amounts to 59.4 euros.

This example serves to illustrate the practical application of the penalty scheme, where households exceeding predefined energy consumption thresholds are subject to fines based on the excess carbon emissions they produce. The interplay between energy consumption, carbon emissions, and carbon pricing is manifest in this calculation, providing a tangible manifestation of the penalty scheme's impact on incentivizing energy efficiency.

5.2.1 Household Energy Allowances and Fines

The forthcoming scheme constitutes a dynamic framework tailored to revolutionize household energy consumption practices, encapsulating a comprehensive strategy that diverges from the traditional trajectory followed by the EU Emissions Trading System (EU ETS). While the EU ETS mandates a gradual reduction in allowances over time for carbon-intensive industries, this novel scheme for conscious energy users operates under a distinct paradigm.

Anticipating implementation, it is integral to acknowledge that each household's energy allowances will remain static. Unlike the diminishing allowances within the EU ETS, these allowances are set to persist without diminution over the years. Modifications to allowances will be initiated solely in response to changes in household circumstances or if the local government mandates alterations to the allocated allowances under specific circumstances.

The rationale for preserving unchanging allowances derives from the core objective of this scheme—to foster motivational schemes that facilitate conscious energy consumption. This emphasis pivots to educating individuals about tailored energy reduction strategies that align with their existing needs, thereby eschewing the need for radical operational transformations. It is paramount to discern that, despite contributing to global carbon emissions, household impact diverges substantially from that of heavy-polluting industries. Thus, the scheme refrains from lowering household allowances as heavy industries do, particularly in the initial years of implementation.

As time advances, the landscape of carbon prices is forecasted to evolve significantly. Projections suggest that carbon prices could surge to an estimated 410 euros per ton of CO2 by 2050, with additional measures integrated—a marked contrast to current carbon valuations. This substantial shift underscores the overarching premise of this scheme: to prompt a profound change in the energy utilization patterns of conscious users.

5.2.1.1 Addressing Non-Compliance and Extensive Consumption

Nevertheless, a pragmatic awareness that non-compliance may persist among specific segments of households remains integral to the scheme's design. Particularly, affluent households may opt to bear fines rather than adjust behaviours. In response, stringent measures are conceived to deter extreme energy consumption.

Supplementary fines, benchmarked against international carbon prices, will be imposed for households exhibiting exceptional energy consumption. This fine augmentation is earmarked for both sporadic instances of extreme energy consumption and persistent excesses, extending over a span of at least five years. However, the integration of these additional fines is envisaged after the initial five years of the scheme's introduction. This incubatory interval mirrors the conceptualization stage of the EU's 'cap and trade' pilot.

5.2.1.2 Additional Fines

The envisaged structure of additional fines is layered, contingent on the percentage of energy consumption surpassing yearly allowances:

- Less than 30% excess: No additional fine
- 30.1% - 40% excess: 100 euro fine
- 40.1% - 50% excess: 250 euro fine
- 50.1% - 60% excess: 450 euro fine
- 60.1% - 70% excess: 700 euro fine
- 70.1% - 80% excess: 1000 euro fine
- Beyond 80% excess: To be determined by a committee

For households with surplus energy allowances from previous years, immunity from additional fines is conferred, even if yearly excesses exceed 30%. Additional insights into using surplus energy allowances are expounded upon in the '5.1 Motivational Awards Schemes' section.

It is crucial to emphasize that all accrued penalties are directed to the government and channelled explicitly to the Department of Energy. This design choice ensures a streamlined approach to fund allocation and underscores the governmental role in fostering energy-conscious behaviours, promoting sustainability on a collective level.

5.3 Thoughts and Considerations

A paramount facet of the seamless implementation of the devised motivational schemes within the D^2EPC project resides in the comprehensive assessment and evaluation of the unique circumstances pertaining to each household. This pivotal endeavour stands as a cornerstone in the allocation of energy allowances that aptly align with the distinct energy requisites of every dwelling.

Central to the efficacy of this approach is the cyclical evaluation of personal considerations of each household. The underlying rationale is rooted in the recognition of the dynamic nature of household needs. An annual assessment serves as a baseline, ensuring the allowances accurately reflect the evolving energy demands. However, a more pragmatic and insightful approach advocates for seasonal evaluations, particularly pertinent for regions characterized by distinct climatic cycles. By embracing a seasonal rhythm, the allowances can dynamically mirror the fluctuating energy requirements intertwined with varying weather conditions.

A poignant example lies in regions where climatic fluctuations induce variances in energy consumption. Such disparities are pronounced in locales subjected to diverse climatic seasons. Notably, a correlation

emerges between intensified energy needs and climatic extremities. For instance, in summer, the dual impact of heightened temperatures and school holidays engenders elevated energy demands, a confluence that necessitates responsive allowances.

In advancing the initiative, meticulous documentation of individual household needs assumes paramount significance. A comprehensive delineation, readily accessible to the public, augments the transparent communication of the enforcement and evaluation protocols underpinning the motivational plans. This strategic dissemination contributes to an informed populace, thereby fostering informed decisions conducive to enhanced energy efficiency.

5.3.1 Holistic Household Considerations

Encompassing an array of factors, the framework for household considerations includes:

- The number of adults and their work arrangements.
- Composition of school-aged children and non-school-aged children.
- Presence of retired individuals or those who remain at home.
- Personnel such as cleaners, nannies, or medical providers.
- Healthcare needs and medical devices require power.
- Architectural features like lifts and swimming pools.
- Adoption of renewable energy sources like photovoltaics.
- Geographical location and climate peculiarities.
- Building characteristics and heating/cooling mechanisms.
- Property type and surface area.
- Presence of electric car charging stations.

In more detail, these household considerations could be the following:

- Number of adults living within the household
- Number of adults working in the household (out of the house)
- Number of adults working hybrid
- Number of adults working remotely
- Number of school-aged children (6-16years) in the household
- Number of children not obliged to be in school (children under 6 years old) in the household
- Number of retired individuals in the household
- Number of adults that do not work and are home daily
- Number of full-time 'staff' living in the household (cleaners, nannies, medical providers (nurses))
- Number of part-time individuals' working' in the household (cleaners, nannies, medical providers (nurses) that do not live full time in the household, rather come and go as needed)
- Number of individuals with medical needs that need to be at home
- Lifts inside the household (considerations will be taken based on whether there is a need to have the lift (individuals that have mobility issues vs. if it is a luxury)
- Swimming pool on the property (luxury vs. medical issues)
  - Is it heated? If so how is it heated?
  - Is it covered if outdoors?
  - Is it an indoor pool?
- Medical devices that require plugging into wall outlets or heavy charging within the household (oxygen machines?)
- Photovoltaics
- Primary residence
- Secondary residence (vacation home) allowances could be halved for vacation homes

- Electric car charging station
- Geographic location of a household – mountainous region vs. city regions vs. coastal regions
- Surface area of household (how big it is)
- Property type: Detached vs. semi-attached vs. apartment in block of flats
- Heating type (traditional heaters vs. air conditioning (air-conditioning keeps rooms warm whilst it is working, once turned off, heat is lost easily))
- Insulation

It is imperative to highlight that energy-intensive considerations should not precipitate automatic penalties. Rather, the allowances are astutely tailored to the specific individuals comprising each household. The fundamental principle driving this calibration is the discernment between needs and luxuries, assuring that allowances resonate with essential requirements. The motivational scheme is custom-tailored to fine-tune energy consumption in alignment with genuine needs, not indulgences.

The underlying aspiration of this approach is not to wield restrictions but to mold behaviors. The scheme catalyzes a shift in daily practices by empowering households to align their energy consumption with necessities. The objective isn't to impose hardships but to inspire mindful energy consumption, advocate for energy-efficient technologies, and endorse environmentally conscious practices.

5.3.1.1 Guiding Penalties and Awards

Within this intricate framework, clear guidelines are indispensable to govern penalty enforcement. Sections 5.2 and 5.3 of this document delve into exhaustive analyses of award and penalty schemes. This comprehensive exploration delves into the fine details, intricacies, and justifications of these pivotal aspects, enabling informed and judicious decision-making by homeowners and tenants in their pursuit of creating energy-efficient households.

The bespoke evaluation of personal considerations for energy allowances stands as a linchpin within the D^2EPC project's motivational schemes. This intricate process not only aligns energy consumption with genuine needs but also stimulates responsible energy practices. This approach heralds a transformative journey towards sustainable and conscientious energy consumption practices by harmonizing allowances with realities and aspirations.

5.3.2 Further considerations

In the pursuit of formulating motivational schemes poised to navigate the intricacies of our multifaceted society, a profound recognition of the societal complexity underscores the meticulous design of the proposed scheme. This intricate framework, aimed at evaluating and accommodating individual considerations, calls for an encompassing perspective that extends beyond the conventional. The ensuing exploration delves into these nuanced dimensions, surmounting the not-so-straightforward inquiries that are intrinsic to the scheme's holistic nature.

As society is complex and this scheme looks to evaluate and take into consideration individual considerations for the motivation schemes, some not-so-straight-forward considerations should be taken into account, such as:

- Can allowances be transferred between properties owned by the same individual?
- Can allowances be sold to other households? If so, at what price and how many allowances?
- What happens when individuals own property but also rent?
- What will the allowances be for holiday homes?

5.3.2.1 Interplay of Ownership and Allowance Transferability

A pivotal facet that necessitates contemplation revolves around the potential transfer of allowances amid properties under the ownership of a singular individual. The inquiry arises: Can allowances be seamlessly exchanged between properties owned by the same individual? This seemingly intricate query presents an avenue for addressing the dynamic nature of property ownership within a contemporary societal framework. The exploration of this aspect embarks upon a journey to decipher the operational feasibility and ethical implications of such intra-owner allowance transfers.

5.3.2.2 Commodification of Allowances: Sale to Other Households

An equally compelling realm that beckons consideration is the prospect of allowing the sale of allowances to other households. This facet probes the scheme's elasticity, delving into the delicate balancing act between encouraging energy-conscious behaviour and introducing a market-driven dimension. Intricacies such as the determination of an appropriate pricing mechanism and the quantification of allowable allowances per transaction surface as pivotal questions. This inquiry embarks on a quest to establish an equilibrium where the spirit of incentivization converges harmoniously with economic dynamics.

5.3.2.3 Multi-Faceted Property Dynamics

As individuals navigate a modern landscape, the spectrum of property engagement stretches beyond mere ownership. It encompasses scenarios where individuals both own property and engage in the tenancy realm. Herein arises a compelling consideration: How do the motivational allowances accommodate the dynamic interplay between property ownership and tenancy? This facet navigates uncharted waters, seeking to establish a framework that harmonizes divergent yet interlinked realms within the scheme's purview.

5.3.2.4 The Intrigue of Holiday Homes

In a society characterized by diverse residential paradigms, the allure of holiday homes introduces yet another layer of intricacy. The query looms: How shall allowances be allocated for properties deemed as holiday homes? This question delves into the contemplation of seasonal occupancy, sporadic energy consumption patterns, and the inherent challenge of harmonizing allowances with the transient nature of holiday home utilization. This dimension embarks on a quest to ensure equitable treatment while respecting the distinctive energy dynamics of such properties.

Collectively, the not-so-straightforward considerations woven within this scheme's fabric engender an intricate tapestry. By embracing these intricate dimensions, the scheme extends beyond the confines of conventional policy paradigms. It mirrors the comprehensive nature of human existence, acknowledging individuals' diverse trajectories and choices. By illuminating these often-overlooked facets, the scheme aspires to be a testament to the meticulousness of its design, poised to be an exemplar of holistic policy formulation.

In conclusion, the panoramic exploration of these intricate considerations unveils the multidimensional essence of the proposed motivational scheme. Its capacity to accommodate these complexities underscores its potential to be a transformative force, encapsulating the nuances of individual lives while striving for collective energy consciousness. This comprehensive approach propels the scheme into its own realm as it navigates the intricate labyrinth of modern society's energy landscape.

6 Application in D^2EPC case studies

The culmination of the crafted motivational schemes designed within Task 6.4 found practical manifestation in a rigorous empirical testing phase. This phase, integral to the comprehensive approach undertaken by the D^2EPC project, was geared towards examining the real-world impact of the newly proposed motivational schemes. Focused on energy consumption, this pivotal stage hinged on a comparative analysis of energy usage trends over time within pilot study buildings. Notably, the central locus of examination was the New Wing of the Main Campus Building at Frederick University, situated in Nicosia, Cyprus and the nZEB Smart House at CERTH premises in Thessaloniki, Greece.

6.1 Temporal Scope and Data Collection

A concerted effort was invested in ensuring the robustness of the empirical investigation. To this end, data was meticulously garnered over two consecutive years, spanning the months from June to December. This encompassing temporal framework allowed for the capture of variations across diverse seasons, casting light on the dynamic nature of energy consumption patterns. The comprehensive dataset amassed included the following critical facets:

- Total Energy Consumption: A comprehensive record of the building's energy consumption formed the cornerstone of this study. This encompassed the diverse array of energy inputs intricately woven into the building's operational dynamics fabric.
- Atmospheric Temperature: Recognizing the intricate dance between energy utilization and atmospheric conditions, precise records of temperature fluctuations were documented. This ambient temperature data was poised to serve as a pivotal variable in the subsequent analytical endeavour.
- Degree Days: In order to unravel the nuanced interplay between temperature variations and energy demand, the concept of degree days was embraced. This parameter, encapsulating the cumulative temperature deviations from a reference point, enabled a more refined understanding of energy utilization trends.

The overarching objective of this empirical inquiry was to facilitate an equitable and enlightening comparison of energy consumption across two consecutive years. To realize this, meticulous adjustments were implemented based on external temperature variations. By factoring in the influence of both hotter and cooler days, a comprehensive panorama emerged, unfurling the dynamic nature of energy consumption trends.

The empirical validation phase extended beyond the scope of atmospheric temperature variations. Nuanced considerations were invoked, recognizing that the intricate tapestry of energy consumption patterns was woven from a multitude of threads. Adjustments were poised to encapsulate diverse facets, encompassing changes in operational patterns, technological upgrades, and evolving occupancy dynamics.

6.2 Unveiling Insights and Future Implications

The empirical investigation underpins the validity of the proposed motivational schemes and the far-reaching implications for energy-conscious behaviours within the building sector. Insights garnered from this meticulous examination foster a deeper comprehension of the intricate interplay between energy utilization and a spectrum of variables. As the D^2EPC project traverses towards its ultimate culmination, these empirical findings contribute a potent layer of evidence, substantiating the efficacy and potentially transformative impact of the motivational schemes devised.

The empirical validation phase served as a pivotal crossroads, where theoretical propositions met the crucible of reality. The application of motivational schemes and the subsequent comparative analysis of energy consumption trends unveiled a panoramic view of the interplay between policy interventions and tangible outcomes. This rigorous empirical endeavour, grounded in the Main Campus Building of Frederick University, Cyprus, epitomizes the quintessential fusion of theory and practice, fostering a foundation for informed decision-making and transformative change in conscious energy usage within the building sector.

6.3 Elaboration of the Methodology

Within the ambit of this endeavour, the methodological framework employed for assessing energy consumption within pilot study buildings unfolds with meticulous precision. The temporal focus encapsulates two distinct epochs: June 2021 to December 2021, designated as the 'base' period, and June 2022 to December 2022, a pivotal comparison year. The selection of this timeframe is underpinned by strategic acumen, targeting the junctures marked by maximal energy consumption. These months, comprising the zenith of energy-intensive seasons, engender insights pivotal for discerning patterns and variances in energy utilization.

The decision to pivot upon the months between June and December is astutely justified by the climatic idiosyncrasies exhibited across diverse locales, where either four or two distinct seasons manifest. This dichotomy unfurls a canvas characterized by extreme temperatures, with scorching summers and frigid winters. This pronounced polarity constitutes an analytical advantage, providing an unambiguous vista for comprehending energy consumption dynamics and concomitant behavioural adjustments.

A paramount facet of the methodology lies in the synchronization of data values, ensuring that comparability is upheld across the two years under scrutiny. This synchronization transcends mere dates, anchoring instead to the days of the year. This erudite approach circumvents the discrepancies arising from disparities between weekdays and weekends, yielding a robust and accurate basis for juxtaposition.

Central to this methodological underpinning is the computation of degree days—a measure that epitomizes the interplay between temperature and energy consumption. A standardized baseline temperature of 18^{o}C forms the foundation upon which degree days are calculated, delineating instances of cooling and heating. The calculated degree day values of 2021 and 2022 set the stage for a pivotal analysis aimed at discerning trends and deviations.

At the crux of this analysis is the formulation of the Degree Day Adjustment Ratio, a pivotal metric quantifying the relative variations in degree days between the two years. This ratio, emblematic of the energy consumption dynamics, unfurls through meticulous calculations, serving as a lodestar for the subsequent adjustments.

Through the synergy of the Degree Day Adjustment Ratio and 2022 energy consumption values, a nuanced narrative emerges. The application of the ratio to energy consumption data for 2022 bestows an 'Adjusted Energy Consumption,' an essential barometer that encapsulates the refined, temperature-normalized energy utilization patterns for that year. The subsequent comparative analysis, juxtaposing the 'base' year's total energy consumption with the adjusted counterpart of the comparison year, becomes the crucible for discerning pivotal trends.

Degree Days $_{2021}$ / Degree Days $_{2022}$ = Degree Day Adjustment Ratio

A discerning eye is cast upon the outcomes of this analysis. When the adjusted energy consumption for 2022 surpasses the 2021 values, a distinctive escalation in energy utilization is manifested between the two years. Conversely, if the cumulative adjusted energy consumption for 2022 falls below the 2021 threshold, a palpable decline in energy utilization emerges as a noteworthy trend.

Energy Consumption $_{(per\ day\ of\ 2022)}$ * Degree Day Adjustment Ratio $_{(per\ day\ of\ 2022)}$ = Adjusted energy consumption based on degree days

In conclusion, the methodological trajectory traversed in this endeavour is a testament to its meticulous design and intricate execution. Rooted in strategic temporal selection, synchronization of data, and an astute calculation of degree days, this methodology stands as a beacon, illuminating the pathways to discerning energy consumption dynamics with precision and discernment.

6.4 Considerations and Limitations

In embarking on a comprehensive exploration of energy consumption dynamics, it is imperative to recognize the multifaceted considerations and limitations that underlie the temporal scope encompassing June 2021 to December 2021, as well as June 2022 to December 2022. Within this purview, a host of factors wielded notable influence, with certain aspects pertinent to the pilot studies executed, while others held universal relevance across all pilot studies.

6.4.1 Impact of COVID-19 Restrictions

An epochal turning point materialized on March 11, 2020, when the World Health Organization formally declared the global ascent of the COVID-19 pandemic, a designation sustained until May 5th, 2023. An all-encompassing ripple effect ensued, prompting the enforcement of stringent restrictions worldwide to safeguard communities from the contagion's grip. This safeguarding impetus indubitably engendered a seismic shift in resource demands, as well as in the intricate tapestry of energy supply and utilization.

The workplace domain bore witness to transformative adaptations, epitomized by the widescale adoption of remote work paradigms or hybrid models. Akin to global trends, the pilot study executed in Cyprus and Greece bore the hallmark of this hybrid approach. A calibrated fusion of remote work and on-premises presence was instated, effectively curbing both office footfall and workdays at the premises. This strategic calibration engendered discernible alterations in energy consumption patterns across the stipulated years.

6.4.2 Dynamics of Personnel, Activities, and Equipment

As the mosaic of energy consumption unfolded, a central facet emerged—pertaining to the dynamics of personnel, activities, and the evolving ensemble of equipment within the building's ambit. An all-encompassing comprehension of energy utilization necessitates an acknowledgement that the matrix transcends exterior temperature parameters.

The cogency of these intrinsic variables was acutely manifested as changes in personnel roles, activities, and equipment configurations unfurled. Often imperceptible yet profoundly impactful, these nuances are intricately intertwined with the energy consumption tapestry. Thus, the energy quotient is not an isolated outcome of external factors; rather, it pulsates in resonance with the building's internal dynamics.

6.4.3 Data Accuracy

The voyage into meticulous data analysis and empirical testing surfaces a crucial facet—data accuracy. Specifically, within the precincts of the Cyprus-based New Wing building case study, the accrued dataset showcased certain gaps that cast a slight shadow upon the veracity of the comparison undertaken. Unfortunately, the measured energy consumption trajectory did not traverse the entire spectrum of parameters, evoking an element of incompleteness within the initial dataset.

This partiality within the dataset introduced a pivotal point of scrutiny, as the analysis hinged on precise data delineation. The incompleteness of the data spectrum inherently translated to an augmented margin of error within the inter-year comparison. This, in turn, raises the imperative of robust data accumulation, accentuating the significance of methodological precision.

In conclusion, within the temporal expanse spanning June 2021 to December 2022, a tapestry of considerations and limitations is intricately interwoven to shape the contours of energy consumption dynamics. From the palpable influence of COVID-19 constraints to the evolving interplay of personnel and activities, these dimensions, encapsulated within the pilot study, are representative of a broader, universally relevant canvas. Furthermore, the caveat of data accuracy foregrounds the quintessence of meticulous data accumulation, permeating every facet of the endeavour to engender informed analyses and discerning insights.

6.5 Pilot Studies and Comparative Energy Consumption Analysis

6.5.1 New Wing Main Campus Building, Frederick University, Nicosia, Cyprus

A pilot study was undertaken to evaluate the tangible impact of the developed motivational schemes from the purview of Task 6.4. This undertaking encompassed an in-depth analysis of energy consumption patterns over the course of two pivotal years, 2021 and 2022. The elucidation of this chronicle not only offers insights into the efficacy of the motivational schemes but also reveals intricate nuances that govern energy utilization within the context of the New Wing main campus building.

6.5.1.1 Energy Consumption Metrics

The chronicle of energy consumption unfurls as follows:

- 2021 Total Energy Consumption: A sum total of 50,191.25413 kilowatt-hours (kWh) of energy was consumed in the year 2021.
- 2022 Adjusted Energy Consumption: The subsequent year, 2022, witnessed a notable increase in energy demand, reaching 72,531.54511 kWh.
- Consumption difference between 2021 and 2022 = 22,340.29098 kWh
- There was an overconsumption of energy used in 2022 compared to 2021.

6.5.1.2 Comparative Analysis

A critical examination of the consumption data for the two pivotal years elucidates a conspicuous transformation. The variance in energy consumption between 2021 and 2022 amounted to a substantial 22,340.29098 kWh. This disparity, evocative of an increased energy demand, underscores

an overconsumption of energy during the latter year, signifying a departure from the precedent set in 2021.

In light of these findings, it is apparent that there has been a discernible surge in energy consumption between the comparative years. However, it is crucial to interpret these results within a holistic context. While the calculated values provide quantitative evidence of an increased energy footprint, comprehensive considerations are imperative to arrive at a nuanced understanding of the underlying causative factors. A judicious interpretation necessitates an exploration beyond mere numerical juxtaposition. While the data is instructive, it is imperative to acknowledge the constraints inherent in this analysis.

Drawing inspiration from the motivational schemes incubated through Task 6.4, an intriguing contemplation emerges. It becomes evident that guided by these schemes; a scenario might have arisen wherein the New Wing main campus building would have faced substantial penalties for their perceptible overconsumption of energy in 2022. Yet, it is incumbent upon us to exercise caution in arriving at definitive conclusions.

6.5.1.3 Limitations and Future Prospects

Several aspects warrant meticulous consideration. This study, despite its meticulousness, has inherent limitations. The comparative analysis, while illustrative, falls short of comprehensively examining all pertinent variables. Furthermore, the absence of complete energy consumption data for the baseline year 2021 introduces a notable limitation, impacting the accuracy of our deductions.

As this data collection and analysis voyage unfolds over the forthcoming years, it promises to furnish a richer and more nuanced depiction of energy consumption trends. The prospect of a more robust comparison, underpinned by complete and refined data, beckons. This underscores the iterative nature of such studies, wherein each successive iteration refines our comprehension and offers a progressively clearer insight into the intricate realm of energy utilization.

In summary, the pilot study encapsulates a significant stride in comprehending the interplay between energy consumption and motivational schemes. It underscores the importance of context, acknowledges limitations, and sets the stage for an evolving discourse that promises to catalyze more informed and impactful energy-conscious decisions in the future.

6.5.2 CERTH Smart House, Thessaloniki, Greece

In the pursuit of quantifying the discernible impact of energy efficiency measures, a meticulous examination of energy consumption data spanning the years 2021 and 2022 was undertaken. The comprehensive assessment aimed to decipher patterns, transitions, and potential driving factors that contributed to the observed shifts in energy consumption dynamics. The elucidation of these insights holds profound implications for households and buildings aspiring to enhance their energy-conscious behaviors.

6.5.2.1 Energy Consumption Metrics

The chronicle of energy consumption unfurls as follows:

- 2021 total energy consumption = 23030 kWh
- 2022 total adjusted energy consumption = -93.75 kWh
- Consumption difference between 2021 and 2022 = -23123.75 kWh
- There was an underconsumption of energy used in 2022 compared to 2021.

6.5.2.2 Comparative Analysis

Within this evaluative framework, the energy consumption landscape was scrutinized. The year 2021 witnessed a total energy consumption of 23030 kWh, offering a baseline metric against which subsequent variations could be juxtaposed. A noteworthy deviation emerged in 2022, with a total adjusted energy consumption of -93.75 kWh recorded. The pronounced consumption difference of -23123.75 kWh between the two years underscored a remarkable shift in energy dynamics, with 2022 showcasing the underconsumption of energy when compared to its antecedent, 2021.

6.5.2.3 Limitations and Future Prospects

The nexus between these energy consumption statistics and the Smart House serves as an illuminating case study. Functioning as a family home for a standard four-member household—a representation mirroring the average European domicile—the Smart House is a microcosm reflecting broader energy consumption trends.

Within the temporal confines of the base year, extending from 1 June 2021 to 22 December 2022, consistent energy consumption was a prominent feature. This steady-state scenario was juxtaposed with the test year of 2022, spanning 2 June 2022 to 22 December 2022. A staggering contraction of nearly one-tenth of the previous energy consumption was observed during this test phase. An inference that emerges assuming the fidelity of energy consumption readings, attributes this pronounced reduction to the assimilation of energy-efficient household appliances and, intriguingly, the potential adoption of alternative energy sources beyond the conventional electricity grid. Photovoltaic panels, exemplifying an alternative energy source, appear as a viable candidate for catalyzing this paradigm shift.

This transformation in energy consumption paradigms offers a clarion call to households and buildings alike to embrace a trajectory of energy efficiency. The Smart House case resounds as a testament that energy-saving appliances and the adoption of green energy alternatives yield substantial dividends.

Undoubtedly, photovoltaic panels emerge as beacons of transformative change. Their efficacy in reducing energy dependence on the grid—long acknowledged—achieves renewed salience within the purview of Project D^2EPC. This augments the value proposition of motivational schemes, wherein the Smart House's energy consumption places it comfortably within the ambit of awards schemes. The potential advantages bestowed by these schemes confer accelerated returns on investments in photovoltaic panels. Additionally, this alignment engenders a potent motivational impetus for households, aligning interests with renewable energy sources and energy-efficient equipment.

The resounding success of the Smart House transcends the realm of mere illustration; it underscores that energy efficiency is an attainable reality within grasp. Beyond photovoltaic panels, the resonance of this achievement radiates a profound message—through concerted efforts, households can ascend the energy efficiency threshold stipulated by the guidelines of the Deliverable. In doing so, the empowerment to partake in award schemes becomes a compelling incentive, generating a ripple effect that fuels the momentum of sustainable practices. The Smart House thus serves as an emblematic clarion call—a potent call to arms—for the amalgamation of renewable energy adoption, energy-efficient technologies, and the rewarding embrace of motivational schemes, amplifying the collective journey toward a greener, more sustainable energy future.

7 Conclusions

Based on the theoretical and data analysis performed in this deliverable, there is concrete evidence of the dire need for stricter motivational schemes to combat buildings' energy consumption. The existing schemes in MSs do not penalize individual buildings/households but only offer financial aid and assistance to upgrade to more energy-efficient equipment. As a result, this does not act as either an incentive or a deterrent for the efficient and successful decrease in energy consumption in household builds.

In the aftermath of a comprehensive and rigorous blend of theoretical exploration and empirical data analysis, the quintessential imperative for robust and stringent motivational schemes to counterbalance the escalating energy consumption within buildings emerges unequivocally. The extant paradigms of MSs' energy policies have revealed limitations in their efficacy. These current schemes, predominantly centred around financial assistance for transitioning to energy-efficient equipment, lack the requisite potency to serve as true catalysts for substantial energy consumption reduction within household structures.

Drawing a salient lesson from the monumental endeavour of the EU Emissions Trading Scheme (EU ETS), it becomes evident that a formidable framework must buttress the architecture of nascent motivational schemes. This infrastructure could galvanize tangible change by dint of financial penalties coupled with equally potent rewards. The efficacy of this twin approach has been incontrovertibly demonstrated by its ability to orchestrate swift and transformative shifts in behaviour. Notably, it has transcended its role as a mere instigator of change, spurring advancements in technology through a surge in research and development endeavours—the outcome: a proliferation of more cost-efficient, energy-saving technologies.

Indeed, the empirical journey embarked upon through pilot case studies substantiates the profound impact of personalized considerations. The pivotal role that personal circumstances play in the quest for effective implementation of energy allocation allowances emerges resoundingly. The energy demands of a household, inextricably linked with its individual context, become paramount. As such, the veracity and precision of energy allocations become non-negotiable. The ramifications of erroneous allocations are two-fold: unjust punitive measures for households and the resultant potential for discord among the general populace.

A vital facet of the trajectory to sustainable energy utilization involves unveiling the distribution mechanism of energy allowances to the public. Transparency in this process and equitable allocations attuned to genuine requirements possess a transformative power. When armed with a tangible comprehension of how allocations align with their actual needs, individuals are emboldened to partake in the energy-saving journey. The juxtaposition of personal energy needs against allocated allowances forms a nexus that spurs behavioural change toward increased energy efficiency.

In the broader vista of conscientious energy use, these conclusions unveil a trajectory underscored by meticulous personalization, transparency, and equitable distribution. With these principles as its guiding compass, the endeavour to reduce household energy consumption stands to not only succeed but also to resonate with the core of societal values and aspirations.

In conclusion, although the motivational schemes developed are extremely promising in effectively reducing the energy consumption of households, the vanguard of their effectiveness hinges on the pivotal consideration of individual needs. The formidable potential for misconstrued allocations mandates a recalibration of our approach. The premise of true efficacy necessitates the harmonization of energy allowances with the authentic needs of households and their occupants. This synthesis is a potent recipe for steering clear of punitive missteps, fostering compliance, and engendering societal harmony. This touches on the need for re-evaluation of personal needs in order to reflect the true needs of the households and their occupants.

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