# Energy Demand Management to fulfilling EU climate commitments

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# Summary

The European Union is at a pivotal point in its energy transition, balancing the need to manage energy demand management (EDM) policies with clean energy investments. This integrated approach is essential for reducing energy consumption, enhancing supply-demand flexibility, and advancing toward a decentralized, climate-neutral energy system by 2050.

## EDM Core Strategies

EDM policies are pivotal in advancing sustainability across Europe, delivering tangible benefits such as reduced greenhouse gas emissions, enhanced energy security, and lower energy costs. By leveraging strategies including behavioural changes, energy efficiency measures, demand flexibility, and sufficiency approaches, EDM has become a cornerstone of the EU's sustainable energy transition. With frameworks like the Energy Services Directive (2006) and the Energy Efficiency Directive (2012), the EU has shifted from fragmented national efforts to a cohesive regulatory strategy, mandating Member States to develop and regularly update National Energy Efficiency Action Plans (NEEAPs) and National Energy & Climate Plans (NECPs) to achieve and enhance ambitious targets.

## Challenges and Gaps

Despite these achievements, EDM faces significant challenges that threaten its long-term impact. Key barriers include the need for widespread behavioural change, the cultural diversity of energy practices across Europe, and the insufficient investment in lasting energy efficiency measures.

## Strategic Recommendations for Policymakers

For EDM to reach its full potential, the report provides key elements to consider by EU policymakers:

1. Adopt a **holistic approach**: Recognize the interconnectedness of energy systems to address supply-demand alignment, grid flexibility, and renewable integration. Balancing these elements is essential to transition toward a low-demand, decentralized energy system that supports the EU's 2050 climate neutrality goals.
2. Design **targeted interventions**: Develop policies adapted to specific regional and cultural energy usage patterns across Europe, as standardized approaches may be less effective in addressing the diverse needs of member states.
3. Ensure **policy stability:** Provide clear, consistent policy directives to build confidence among stakeholders and encourage long-term investments in energy-saving technologies, which is crucial for reaching energy efficiency targets set by the EU.
4. Commit to **continuous monitoring and evaluation**: Establish robust mechanisms to track the effectiveness of EDM policies, assess rebound effects (where efficiency gains may lead to increased consumption), and ensure equitable distribution of benefits across society.
5. Invest in **public engagement and education**: Boost energy literacy to empower households and businesses to make informed energy choices, building broad societal support for EDM policies.
6. Offer **financial incentives** for energy efficiency: Make energy efficiency improvements affordable, particularly for low-income households, through accessible funding, helping to prevent social disparities in access to sustainable energy solutions.

## Behavioural Insights and Social Science Integration

The report emphasizes the necessity of integrating insights from social sciences and humanities into EDM policies. Recognizing that successful energy policies must account for consumer behavioural drivers, such as values, intentions, and attitudes, the EU is encouraged to design user-centric policies that resonate with diverse public needs and lifestyles. This approach ensures that policies are not only technically sound but also socially accepted and with greater impact.

Through these strategies, the EU can build a resilient, low-carbon energy system that meets the unique needs of its citizens while driving toward its 2050 climate goals. EDM, supported by strategic policy alignment, financial accessibility, and a commitment to social consideration and inclusivity, can redefine Europe’s energy landscape, ensuring that the transition is both environmentally and socially responsive.

# List of abbreviations

| ABBREVIATION | NAME |
|---|---|
| **ETS** | *Emissions Trading System* |
| **CCS** | Carbon Capture and Storage |
| **CCU** | Carbon Capture and Utilization |
| **CET** | Clean Energy Transition |
| **EED** | Energy Efficiency Directive |
| **EDR** | Energy Demand Reduction |
| **EDM** | Energy Demand Management |
| **EEOS** | Energy Efficiency Obligation Schemes |
| **EED** | Energy Efficiency Directive |
| **EPCs** | Energy Performance Certificates |
| **EU** | European Union |
| **FCM** | Fuzzy Cognitive Mapping |
| **EV** | Electric Vehicles |
| **MS** | Member States |
| **NECP** | National and Energy Climate Plan |
| **NZEBs** | Near Zero Energy Buildings |
| **RE** | Renewable Energy |
| **RED** | Renewable Energy Directive |
| **PaMs** | Policies and Measures |
| **SRoI** | Social Return on Investment |
| **TAM** | Technology Acceptance Model |
| **TBP** | Theory of Planned Behaviour |
| **TRA** | Theory of Reasoned Action |

# 1 Introduction

Recent geopolitical events such as the Russian invasion of Ukraine have intensified the need for an energy transition in Europe. The vulnerability of our current energy systems, particularly dependence on volatile oil and gas supplies, has become increasingly evident. This has shifted the traditional **energy trilemma** (balancing security, affordability, and sustainability) with security taking centre stage. As a result, some countries are prioritizing immediate energy security over long-term sustainability and social inclusion goals, potentially delaying, or scaling back green energy initiatives and increasing the social gap. However, accelerating the energy transition is crucial for achieving long-term energy security, price stability, and EU resilience. Under current conditions, Energy Demand Management (EDM) has emerged as a crucial tool for addressing energy challenges.

EDM encompasses three key components: **(1) energy efficiency**, **(2) demand-side practices**, part of direct energy demand reduction (EDR) strategies, and **(3) demand flexibility**, which involves shifting energy demand to more optimal times. EDR demand reduction focuses on decreasing the overall consumption of energy, while demand flexibility refers to the adjustments needed in a future energy system to balance supply and demand (Barrett et al., 2022).

Originally conceived in response to the oil crisis, EDM offers a compelling case in today's context due to several key factors. On the one hand, European countries have been including energy efficiency obligations by means of new and updated legislation over the past several years, eventually leading to optimized energy consumption (Bertoldi & Mosconi, 2020). This focus on efficiency is complemented by a gradual shift in consumer mentality, driven by efforts from public authorities and academics to improve our understanding on consumer behaviour in general and energy savings practices in particular. Additionally, the concept of energy sufficiency, which advocates for responsible consumption without sacrificing well-being, is gaining traction, with some countries cautiously introducing policies and initiatives to reduce baseline consumption demand (Best et al., 2022). Technological advancements are also propelling EDM forward, with smart grid integration, increasingly energy efficient appliances, and advanced data analytics driving dynamic demand management and targeted interventions.

The importance of EDM is therefore gaining momentum in recent years, backed by substantial evidence. For instance, IRENA's 1.5°C pathway identifies EDR as one of six technological avenues essential for reducing emissions by 2050 (International Renewable Energy Agency, 2023). This pathway emphasizes electrification and efficiency, supported by renewables, hydrogen, and sustainable biomass, which together could decrease nearly 37 gigatonnes of annual $CO_2$ emissions by 2050. Notably, IRENA estimates that 25% of this reduction will stem directly from EDR efforts, achieved through both reduced demand and efficiency improvements (International Renewable Energy Agency, 2023). This is notable as energy demand in Europe has remained relatively stable over the past 20 years (Odyssee-Mure, December 2023). Between 2000 and 2020, final energy consumption in the EU increased slightly from 923.3 Mtoe to 932.4 Mtoe (almost 1% rise). This suggests there is potential for further reduction, as current consumption still exceeds sufficient levels (Zell-Ziegler et al., 2023).

While rapid advancements in renewable energy technologies, such as solar and wind power, offer significant potential for decarbonizing our energy systems, a sole focus on grid electrification might not be sufficiency to reach climate neutrality (EDF, 2022) while not harming significantly other environmental dimensions. Despite falling costs, the production of renewable energy technologies remains resource-intensive, often relying on finite materials extracted from locations outside of Europe (Ahmed et al., 2022) and the recycling infrastructure for these materials, which is still in its infancy (Heath et al., 2022), need to be developed. Despite recycling options, renewable energy generation carries environmental impacts, including effects on biodiversity (Krupnik et al., 2022). Recent scenario developments at the EU level highlight the importance of balancing renewable energy (RE) expansion with EDM to achieve cost-effective decarbonization. This integrated approach is supported by multiple studies, including the European Commission's 2040 ex-ante assessment report, which emphasizes the need for a comprehensive strategy that combines accelerated renewable deployment with enhanced EDM measures (European Commission, 2023). The LIFE scenario outlined in the report underscores the significance of considering both RE development and EDR in tandem as a way to reach the same climate targets with reduced investment requirements (European Commission, 2023). Reinforcing this perspective, calculations by the Institut Rousseau's "*Road to Net Zero*" scenario claims that combining RE expansion and EDM is crucial for optimizing the decarbonization pathway (Institut Rousseau, 2024). Similarly, I4CE (Institute for Climate Economics) investment pathway scenario demonstrates how coordinated development of RE and EDM can lead to more resilient decarbonization strategies (I4CE, 2024).

## 1.1 Direct benefits of EDM

Historically, long-term climate change mitigation plans have focused on developing low carbon energy sources (supply-side), often relying on unproven technologies or massive investments. However, reducing overall energy consumption (demand-side) has proven equally crucial in achieving climate and other environmental and social objectives (Creutzig, Roy, et al., 2022). EDM offers several significant advantages and benefits to different stakeholders (Büchs et al., 2023; European Energy Research Alliance, 2023):

1. **Climate impact:** EDM directly addresses climate change by reducing greenhouse gas emissions and mitigating air and water pollution caused by fossil fuels.
2. **Energy security**: Reducing fossil fuel dependence strengthens Europe's energy security.
3. **Economic benefits**: EDM unlocks cost savings for consumers and businesses through energy-efficient technologies and behavioural changes, leading to lower energy bills, improved competitiveness, and reduced need for new power infrastructure investments.
4. **Environmental footprint and circularity**: As Europe transitions to renewable energy, demand management helps mitigate environmental concerns associated with large-scale projects, such as material mining and processing.
5. **Grid stabilization:** EDM plays a crucial role in enhancing grid stabilization while reducing costs. It helps utilities manage peak demand more effectively, reducing strain on the grid during high-demand periods and facilitating the integration of distributed energy resources (DER).
6. **Public health and comfort:** Prioritizing demand management contributes to improved public health and comfort (Creutzig, Niamir, et al., 2022). Energy-efficient buildings minimize reliance on energy-intensive systems, potentially improving air quality, reducing thermal stress, and lowering noise pollution.
7. **Just energy transition**: EDM could enable a more equitable energy transition by targeting high-end consumers' energy demand, potentially allowing for increased energy consumption by low-income households (Büchs et al., 2023).
8. **Decentralization and local control:** EDM promotes decentralization by enabling local users to control their energy loads. This empowerment allows consumers to manage their energy consumption more effectively, participate in demand response programs, and contribute to grid resilience.

## 1.2 Current challenges are asking for a model shift

A robust EDM strategy becomes even more critical given that other promising technological innovations, such as hydrogen, Carbon Capture and Storage (CCS), and Carbon Capture and Utilization (CCU), are showing limitations in terms of rapid and cost-effective implementation (De Kleijne et al., 2022; Rasul et al., 2022). Simultaneously, human behaviour tends to follow a log-normal distribution in economic decision-making (Ialongo & Lago, 2024), which may partly explain why we easily slip into overconsumption patterns that are difficult to change. Inefficient energy use exceeds planetary boundaries and paradoxically impacts societal well-being — while increased consumption is expected to enhance comfort, overconsumption leads to climate and environmental hazards that ultimately reduce it. Historically underrepresented in research and policy, EDM emerges as a promising solution, especially at system and societal levels (Sorrell, 2015). This is related to the fact that EDM relies for its success on good societal acceptability levels, as it often involves changes in lifestyles and behaviours (Hickel et al., 2022). EDM initiatives should be designed to be inclusive and equitable, ensuring that the benefits are distributed fairly across different socioeconomic groups (Büchs et al., 2023). Recognizing the importance of EDM is therefore crucial for driving the energy transition and achieving the goals outlined in the broader Clean Energy Transition (CET) strategy in Europe. However, EDM adoption and impact vary significantly depending on national contexts: some Member States (MS) are in early developmental stages, struggling with inefficiencies, while others are more advanced but face challenges due to high consumption levels. Similarly, levels of public awareness vary widely across populations, presenting unique challenges and requiring tailored strategies for successful implementation across different regions.

## 1.3 Structure and methodology of the report

The report is structured in three sections, as outlined in Figure 1 below.

**Section 1: Historical overview of macro-level trends in energy demand reduction for Europe**

Europe's energy landscape has been shaped by a complex interplay of technological progress, policy innovations, economic transitions, and shifting societal priorities. The first section of the report presents a historical overview of EDM's macro-level trends in Europe, shedding light on pivotal moments that have influenced the continent's approach to energy management. The objective is to extract valuable lessons from these historical experiences which are crucial for shaping future policies toward sustainable and effective energy practices. Beginning with early EDM policies and evolving through periods of energy crises, regulatory shifts, and advancements in renewable technologies, this section offers a narrative that captures Europe's diverse journey in managing energy demand. While focused on Europe, this historical overview also considers international developments, reflecting the interconnected nature of global energy transitions and the broader shifts toward sustainability.

**Section 2: A systemic approach for monitoring and evaluating EDM policies success**

In Section 2, the report shifts from a descriptive to an analytical approach, exploring the factors that have consistently influenced the success of EDM policies, with a particular emphasis on monitoring and evaluation. This section introduces a systemic model that represents the complex web of social, economic, technological, and regulatory factors shaping EDM's impact. By using this model, different scenarios are simulated which allow for an exploration of how the various factors interact and influence one another, highlighting the areas where interventions could yield the most substantial benefits for energy efficiency and sustainability.

**Section 3: Scenario analysis – Tailoring policies through energy literacy and user profiles**

The third section of the report focuses on one scenario tested in the model—"*enhancing energy literacy through customized user profiles*". Recognizing that individuals and communities have unique energy needs, this section explores the impact of tailoring EDM policies to promote energy literacy and better align with users' profiles. This approach underscores the importance of user-centric policies, aiming to empower individuals and communities by making energy-saving practices more accessible, relevant, and actionable. The analysis highlights the potential of these tailored policies to build a more energy-conscious society and facilitate Europe's CET strategy by addressing diverse energy literacy levels and bridging gaps in public awareness.

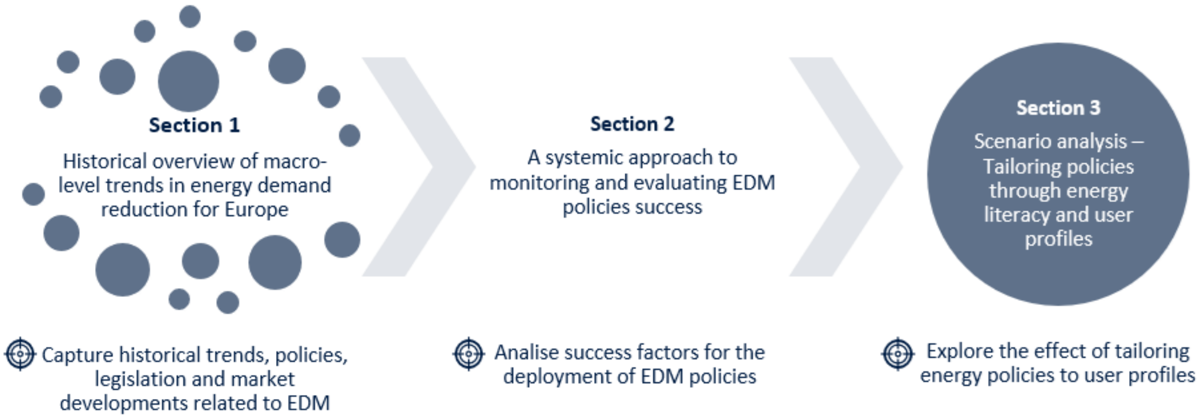


*Figure 1:Overview of the three sections of this report.*

# 2 Historical overview of macro-level trends in energy demand reduction for Europe

## 2.1 A glance at the foundations that underscore the need for the ongoing energy transition

During the first industrial revolution (late 18th to mid-19th century), coal emerged as a crucial energy source driving the transformation of European industries. The transition from manual labour to mechanized production was marked by the widespread use of steam engines powered by coal. The coal industry played a pivotal role in propelling economic growth, particularly in regions like the United Kingdom, Belgium, and Germany (Hubbert, 1949). Following the challenges of First World War and the interwar period, coal maintained its importance in the energy mix. However, technological advancements, including the rise of electricity and oil, began to diversify the energy sources for industrial processes. The coal industry therefore faced competition but still served as a fundamental energy pillar, especially in heavy industries. The second industrial revolution (mid-20th century onward) witnessed a significant shift in the European coal industry. While coal remained a crucial energy source, petrol quickly gained ground, driven by its higher energy density, superior combustion efficiency, and adaptability for mobile applications such as automobiles and machinery.

It wasn't until the 1970s and 1980s that increasing awareness of environmental issues, coupled with a series of events highlighting the growing dependency of European countries on external fossil fuels, especially petrol (e.g., Oil embargo of 1973 or the oil price shock triggered by the gulf war in 1990), prompted European countries to initiate cautious investments in alternative sources of heat and energy (Kander et al., 2014) next to demand reduction and efficient use (Schipper et al., 1989).

The concept of demand reduction gained therefore traction in Europe during the 1970s and 1980s alongside growing environmental concerns and the oil crises. As described in the following section, European countries began exploring various strategies for demand reduction alongside diversification of energy sources.

## 2.2 Key historical events having shaped European energy market and policies

### 2.2.1 Brief overview of historical events

Since the establishment of the European Coal and Steel Community in 1951, which marked a distinct effort to integrate energy resources and foster energy cooperation among Member States (MS), a series of events have influenced the pace of both energy supply diversification and energy demand reduction. As of 2021, the EU27's energy supply consisted of 68% from fossil fuels (coal 12%, natural gas 25%, and oil 32%), 18% from green energy sources (hydro 2%, wind and solar 4%, and biofuels and waste 12%), with the remaining 14% attributed to nuclear energy (IEA, 2024). In the scope of this study, we emphasize pivotal events that have notably shaped the latest European energy strategy, particularly focusing on essential policy measures driving efforts to reduce energy demand *Figure 2*.

*The selected events, serving as antecedents to energy demand reduction policies in Europe, are significant milestones that have left a lasting impact on the energy landscape of the region. These events have influenced policy directions, spurred investments in alternative energy sources, and prompted a re-evaluation of energy policies across EU MS. The chosen events are listed in*

Table 1.

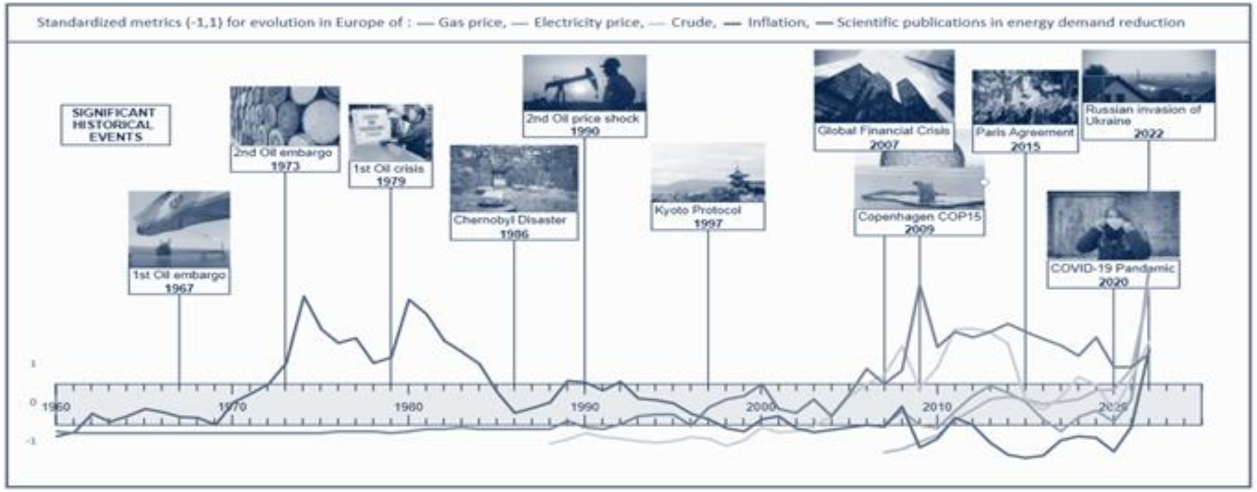


Figure 2:Timeline illustrating key historical events that have influenced the energy market, accompanied by trends in economic and energy indicators (1), as well as research developments in the field of demand reduction (2). The presented trends have been standardized to facilitate comparisons

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1) Inflation data and consumer prices for the European Union are expressed in annual percentage figures and are not seasonally adjusted.

Crude oil prices (Brent) for Europe are represented in dollars per barrel, on an annual basis, and are not adjusted for seasonal variations. This information is sourced from the Federal Reserve Economic Data (FRED) website. Electricity and gas prices for the European Union come from Eurostat.

2) The publication numbers are determined by quantifying articles' metrics obtained after conducting a search on Google Scholar using the terms "energy efficiency," "behavioural energy demand management," "energy sufficiency," and "energy policy" during the specified period.

*Table 1 List of historical events having impacted Energy Demand Management policies in Europe during the last decades.*

| Event | Description |
|---|---|
| **1st Oil embargo of 1967** | Triggered by the Six-Day War in the Middle East, marked a significant turning point in global energy geopolitics. Following the conflict, several Arab oil-producing countries, led by Saudi Arabia, imposed an embargo on oil exports to countries perceived as supporting Israel. This embargo targeted Western nations, including the United States and its allies, causing a sudden disruption in oil supplies and soaring prices in the international market. |
| **2nd Oil embargo of 1973** | The oil embargo, wielded by OPEC as a weapon during the Arab-Israeli conflict, triggered a global shock that significantly impacted the EU's energy market. It underscored Europe's susceptibility due to heavy reliance on oil imports, prompting a pivot towards diversification and energy security policies. However, internal fragmentation among European countries hindered coordinated responses. The crisis also catalysed investments in alternative energy sources, prompting a reassessment of energy policies within EU member states, and fostered increased transatlantic cooperation (Labbate, 2014a). |
| **1st Oil crisis of 1979** | The oil crisis of 1979 was triggered by the Iranian Revolution, which resulted in a substantial reduction in oil production and a rapid escalation in prices. Contributing factors to the crisis included political instability in other oil-producing nations like Iraq and Nigeria, alongside heightened demand for oil from rapidly expanding economies, notably in Asia. These factors combined to create global energy shortages and economic turbulence, with oil prices doubling within a matter of months. |
| **Chernobyl disaster, 1986** | The Chernobyl nuclear disaster, particularly when compared to other incidents like Three Mile Island or Lucens, had an impact of EDM efforts in Europe. The disaster drastically affected public and governmental scrutiny of nuclear energy, raising serious safety concerns that influenced policy decisions across the continent. In the aftermath, many European countries implemented more stringent regulations and reassessed the role of nuclear power in their energy strategies. This led to a shift away from nuclear energy in several nations, prompting a broader reliance on alternative energy sources, primarily coal and gas, and a renewed focus on energy efficiency (Csereklyei, 2014). |
| **2nd Oil price crisis or price shock, 1990** | The oil price shock of 1990, linked to geopolitical events, impacted the EU's energy market by affecting oil-dependent economies and prompting efforts to enhance energy efficiency and reduce reliance on fossil fuels. This shock played a role in shaping energy policies, emphasizing the importance of diversification and resilience to external energy market fluctuations. Today, EU climate policy is expected to offer some protection against the macroeconomic consequences of an oil price rise (Maisonnave et al., 2012). |
| **Kyoto Protocol, 1997** | The Kyoto Protocol marked a milestone in EU climate policy. The results of an analysis confirm that without new policies, carbon emissions in European countries would increase by 14% in 2010 compared to the 1990 level, contrary to the 8% reduction required for the Kyoto Protocol target (Viguier et al., 2003). These policies also committed member to the development of renewable energy sources and energy efficiency measures. The agreement contributed to the establishment of the EU Emissions Trading System (ETS) and laid the groundwork for subsequent international climate agreements. |

| | |
|---|---|
| **Global Financial Crisis, 2007** | The global financial crisis prompted economic challenges that affected the EU's energy market. It led to a reassessment of energy investments, with some countries adjusting their renewable energy ambitions due to financial constraints. At the same time, governments also used stimulus packages to promote energy efficiency and investments in green technologies as a way to spur economic recovery (Goddard et al., 2009). Moreover, the crisis impact on EU decision-making shed light on the role of decentralized decision-making and economic interdependence in European integration, calling for new debates in the topic (Hodson & Quaglia, 2009). |
| **Copenhagen COP15, 2009** | The event marked a pivotal moment in shaping global energy policies emphasising the urgency of transitioning toward a low-carbon energy future. Discussions centred on renewable energy deployment, emissions reduction targets, and financing mechanisms for sustainable development. Although the conference didn't yield a legally binding agreement, it laid essential groundwork for future climate negotiations. |
| **Paris Agreement, COP21, 2015** | The Paris Agreement reinforced the EU's commitment to combat climate change. It set ambitious targets for reducing greenhouse gas emissions and promoting the transition to a low-carbon economy. The agreement influenced the EU's energy policies, accelerating the adoption of renewable energy sources, energy efficiency measures, and the development of innovative technologies (Oztig, 2017). |
| **COVID Pandemic, 2020** | The COVID-19 pandemic impacted the EU energy market by causing fluctuations in demand and disrupting supply chains. Lockdowns and economic challenges affected energy consumption patterns and investments. The pandemic underscored the importance of resilience and adaptability in the energy sector, prompting discussions on the role of clean energy in post-pandemic recovery plans (Mišík & Nosko, 2023). |
| **Russian Invasion of Ukraine, 2022** | The Russian invasion of Ukraine had significant implications for the EU's energy security. It raised concerns about the region's dependency on Russian gas and prompted efforts to diversify energy sources and reducing energy consumption. The geopolitical crisis influenced discussions on energy policy, highlighting the need for strategic planning and cooperation to mitigate external risks and safeguard the EU's energy interests (Aitken & Ersoy, 2023; Mišík & Nosko, 2023). As a result, Russian energy exports to the EU experienced a significant decline of 6.1 billion euros between the first quarter of 2021 and the third quarter of 2022 (Eurostat, 2024a), while natural gas consumption dropped by 19.3% from August 2022 to January 2023, compared to the average consumption during the same months between 2017 and 2022 (Eurostat, 2024b). In the meantime, however the price of energy dramatically increased in 2022, leading to economic and social challenges, before going down again in 2023. |

### 2.2.2 A look at the data trends

An analysis of historical events linked to energy data trends highlights the substantial impact of market shocks, particularly those stemming from the oil and gas sector, on both foreign and EU energy policies. Inflation data depicts three notable peaks corresponding to key fossil fuel (petrol and gas) price shocks: 1973, 1979, and the recent crisis triggered by the Russian invasion of Ukraine in 2022. Each shock exposed Europe's vulnerability to volatile energy markets and spurred a renewed focus on energy security. Following the 1973 oil crisis, the EU began emphasizing diversification of energy sources and demand reduction as key strategies to bolster resilience. This focus on demand reduction manifested in policies promoting energy efficiency. For instance, some countries introduced stricter building codes mandating better insulation and others implemented financial incentives for homeowners to upgrade to energy-efficient appliances (Economidou et al., 2020). From a broader perspective, the EU introduced the initial **Energy Efficiency Directive (EED)** in 2006, which established mandatory national energy efficiency objectives for member states covering both residential and non-residential sectors. Subsequently, in 2010, **the Energy Performance of Buildings Directive (EPBD)** was enacted, aiming to enhance the energy efficiency standards of newly constructed and renovated buildings. These directives have been the foundation for subsequent legislation aimed at reducing energy demand. Additionally, the EU encouraged behavioural changes to curb consumption. Public awareness campaigns promoted energy-saving practices at home, and car-free days were implemented in some cities. While these efforts initially dampened the inflationary impact of subsequent oil price hikes, rising energy demand over the following decades eroded these gains.

The recent crisis in Ukraine has reignited the EU's focus on energy security, elevating energy independence as a pivotal component of its strategies. This renewed focus goes beyond mere diversification efforts. These recent events, coupled with increases in oil and gas prices and past fears of energy security following the 2005 natural gas cutback from Russia (Kavalov & Peteves, 2007), are accelerating the EU's need for new energy sources and a reduction in external dependencies.

This imperative to mitigate energy market shocks aligns with a global shift towards climate change mitigation. The surge in scientific research dedicated to demand reduction policies and stricter regulations on greenhouse gas emissions, as seen with international discussions like COP15 in Copenhagen, reflects this global trend. Furthermore, data correlations in Figure 1 suggest a positive relationship between higher oil prices and intensified research on demand reduction. This suggests that periods of energy insecurity, like the current crisis, can catalyse innovation in technologies and strategies aimed at reducing energy consumption.

The EU's renewed focus on energy independence aligns with broader global trends towards sustainable energy practices. Both internal and external factors are pushing the EU to diversify its energy portfolio, invest in renewable energy, and develop strategies to reduce overall energy demand.

## 2.3 The evolution of energy demand management policy in Europe

### 2.3.1 Crisis as catalyst of major policy changes

Throughout history, major disruptions in energy supply have significantly impacted European energy policy, particularly regarding efforts to reduce energy consumption (see **Error! Reference source not found.Error! Reference source not found.**). Yet, research suggests that even seemingly minor incidents can have significant political consequences, highlighting the impact of "*crisis proximity*" on policy responses (Nohrstedt & Weible, 2010). The Chernobyl disaster in 1986 spurred intense debates on nuclear plant closures, particularly in nearby countries like Sweden and Germany, showcasing the complex interplay between crises, policy, and geography.

These crises act as wake-up calls, forcing a revaluation of energy security and driving innovation. The oil crises of the 1960s and 1970s serve as prime examples. They spurred the implementation of various policies across Europe aimed at securing a stable energy supply for multiple countries. These events exposed Europe's vulnerability to the volatility of energy markets and its dependence on imported oil. In response, several European nations have implemented a range of demand-management policies (Bean, C. R, 1994; Economidou et al., 2020), primarily focused on the following topics, with some of them elaborated for in the text below:

- **Building efficiency:** Stricter building codes were introduced in some countries (e.g., France and Germany), mandating improved insulation, and coupled with financial incentives offered to homeowners to upgrade windows and doors, further reducing heating and cooling needs.

- **Appliance efficiency standards:** Minimum energy performance standards were established for appliances like refrigerators, washing machines, and televisions. This ensured that new appliances were more energy efficient, leading to lower household energy consumption over their lifespan.
- **Fuel pricing and taxation**: Some countries implemented higher taxes on gasoline and diesel, making fuel prices more expensive and encouraging consumers to drive less. This strategy aimed to reduce overall energy demand in the transportation sector.
- **Public awareness campaigns:** Broad public awareness campaigns were launched to educate citizens about energy saving practices at home and work. These campaigns promoted simple actions like turning off lights in unoccupied rooms and lowering thermostats in winter.
- **Urban mobility initiatives:** Cities implemented car-free days and invested in public transportation infrastructure, encouraging a shift towards more sustainable transportation options. Promoting cycling and walking further reduced reliance on personal vehicles.

These initiatives, initially launched at the national level, are gradually transitioning to a centralized approach within the EU as part of a broader continental strategy aimed at addressing energy security concerns by reducing the overall energy consumption. The motivations for this shift are manifold, including efforts to mitigate reliance on external sources by promoting self-sufficiency through electrification and renewable energy. Moreover, the EU facilitates the exchange of best practices and expertise among MS, fostering innovation and the adoption of effective demand-reduction strategies. This centralized approach seeks to forge a more secure and sustainable future by enhancing overall efficiency, diminishing dependence on fossil fuels, and driving innovation in energy-saving technologies.

### 2.3.2 Energy demand management initiatives in the EU-27 from the last decades.

The European Union's heavy reliance on fossil fuels is concerning, and opinions on the pace of transitioning away from these differ depending on the perspective. For some, the transition appears fast as it jeopardizes market competitiveness, while for others, it is not perceived as fast due to the significant environmental and energy security challenges involved. Regardless of perspective, the EU remains a leader in decarbonization efforts, as demonstrated by its robust environmental policies, investments in renewable energy, and emphasis on energy efficiency. However, while energy efficiency improvements have led to a modest decrease in energy consumption per capita, overall consumption has remained stable over the past 20 years, shifting from 925 Mtoe in 2000 to 916 Mtoe in 2022. Significant reductions are often sector-specific and respond to the internalization of industry (see Figure 7 and section Sector-specific variations in energy consumption trends.

In light of these trends, the EU has intensified its policy efforts to address demand reduction, making it a cornerstone of the region's policy landscape. Several key legislations have supported this shift (Economidou et al., 2020) and have been recently revised or amended (see Table 2) to better address evolving challenges and ambitions.

The journey towards a more energy-efficient Europe began with the adoption of the first Energy Efficiency Directive (EED) in 2006. This foundational legislation established a first framework for improving energy efficiency across the EU, setting targets for member states to achieve specific energy savings. Subsequent revisions of the EED in 2012 and 2018 have significantly strengthened the directive's scope and ambition. The 2012 revision introduced more stringent energy efficiency targets, expanded the directive's coverage to include additional sectors, and emphasized the importance of energy audits and energy management systems. The 2018 revision further tightened energy efficiency requirements, introduced new obligations for public buildings, and emphasized the role of digital technologies in improving energy performance.

Successive revisions of the EED (2012, 2018 and 2023) have overall led to some key improvements including:

- **Increased energy efficiency targets:** Revised goals are more ambitious, pushing for greater efficiency across the EU.
- **Broader scope:** Newest versions of the directive now cover more sectors and activities for a fuller approach to energy efficiency.
- **Enhanced policy instruments:** Including new policy tools such as energy audits, management systems, and eco-design requirements to boost efficiency.
- **Strengthened governance and monitoring:** Stronger monitoring and reporting systems that help tracking progress and ensure that targets are met.

In the context of the EED, MS were required to develop National Energy Efficiency Action Plan (NEEAPs) and implement various measures to improve energy efficiency across different sectors. Similarly, the Energy efficiency obligation schemes (EEOS) emerge as national efforts to meet energy saving obligations in frame of the EED. The EEOS have become versatile tools designed to achieve sustained energy savings over time and are tailored to fit national needs and policy frameworks. More than 15 EU countries had already implemented EEOS by 2019 (Fawcett et al., 2019). As per the Eighth State of the Energy Union report released on October 24, 2023, all 27 EU Member States are actively involved in energy demand reduction efforts by formulating and executing their National Energy and Climate Plans (NECPs) in accordance with the EU's Energy Union governance regulation (EUR-Lex, 2023). Near Zero Energy Buildings (NZEBs) and Energy Performance Certificates (EPCs) are other subsequent practical outcomes of EPBD implementation. NZEBs establish a new benchmark for energy efficiency in new constructions, significantly reducing their operational energy consumption. The EPBD introduces progressive requirements for new buildings to align with NZEB standards, ultimately aiming for all new constructions to meet NZEB criteria. Likewise, the EPBD mandates EPCs for buildings. These certificates evaluate a building's energy efficiency and offer a rating system to inform potential buyers or tenants about its energy consumption. Also, directly part of the EPBD legislation and influenced by the Ecodesign legislation, Minimum Energy Performance Standards (MEPS) are another example of derived legislation that helps achieve the EU's overall energy efficiency goals by setting mandatory minimum levels of energy performance for a wide range of products. On its turn, the Waste Framework Directive has encouraged the implementation of Extended Producer Responsibility (EPR) schemes. Under EPR schemes, producers take on some financial and/or organizational responsibility for the collection and recycling of their products at the end of their lifespan.

*Table 2: Energy Demand Reduction legislation in the EU.*

| Policy scheme | Description | Revision date |
|---|---|---|
| Energy Efficiency Directive (EDD) | The Energy Efficiency Directive 2012/27/EU is at the cornerstone of the EU's energy efficiency framework. The EED sets binding national energy efficiency targets for member states across residential and non-residential sectors. | September 2023 |
| Energy Performance of Buildings Directive (EPBD) | The Directive 2010/31/EU on the EPBD focuses on improving the energy performance of buildings throughout their lifecycle. It sets minimum energy efficiency requirements for new and renovated buildings, promotes energy inspections, and requires the issuance of energy performance certificates (EPCs) for buildings. | December 2023 |
| Ecodesign for Sustainable Products Regulation (ESPR) | The Directive 2009/125/EC addresses the environmental impact of energy-related products throughout their life cycle. It sets mandatory Ecodesign requirements for a wide range of products, including their energy efficiency, energy consumption in standby and off modes, reparability, and recyclability. | March 2022 |
| Energy Labeling Directive (ELD) | The Directive 2010/30/EU complements the Ecodesign by requiring specific energy labels to be displayed on a wide range of energy-using products. This empowers consumers to make informed choices based on the energy efficiency of the product, promoting more energy-efficient options. | August 2017 |
| Energy Taxation Directive (ETD) | The Directive 2003/96/EC lays down the framework for taxing energy products like motor fuels, heating fuels, and electricity within the EU. The proposed revision seeks to enhance alignment with EU climate objectives by taxing fuels based on their energy content and environmental performance. | July 2021 |
| Public passenger transport services by rail and by road | Regulation (EC) No 1370/2007 governs public passenger transport by rail and road within the EU. This regulation allows public authorities to financially support (or grant exclusive rights to) operators providing essential services that might not be commercially viable while ensuring a well-functioning public transport system throughout the European Union. | December 2017 |
| Waste Framework Directive | The Waste Framework Directive (2008/98/EC) serves as a cornerstone of the EU's Circular Economy Package. This directive sets ambitious recycling and waste reduction targets for member states. It prioritizes waste prevention, reuse, and recycling over landfill disposal. | February 2024 |
| Critical Raw Materials Act | Although still a **proposal for regulation**, the Critical raw materials act aims to fortify the EU's supply chain for critical materials essential for clean technologies and the green transition. This regulation focuses on diversifying sources, enhancing recycling initiatives, and fostering innovation for efficient resource use. | March 2023 |
| Net zero industry act | Although still a **proposal for regulation**, the Net Zero Industry Act aims to enhance Europe's manufacturing capacity for products necessary to achieve net-zero emissions. | June 2023 |
| Right to repair | The European Commission **proposed new rules** (COM(2023) 1794) to give consumers a "right to repair" their electronic devices and household appliances. This initiative aims to make products more durable, repairable, and recyclable, reducing waste and supporting the circular economy | November 2023 |

These policies and regulatory agendas have established targets and strategies for many European countries regarding their efforts to implement EDM policies. Often, they align with the broader European objectives, aiming to create a unified market and achieve common targets while promoting a resilient economy that ensures energy security and targets net carbon emissions. These common regulations and directives are coordinating the European targets to develop a low-carbon economy while ensuring equity and fostering innovation.

### 2.3.3 Room for improvement and the concept of downsizing policies

Despite the varied and ambitious set of policies, several important aspects remain inadequately addressed or poorly considered in the current context of policy and measures (PaMs) implementation by European countries (Draft National Energy and Climate Plans (NECPs), 2023).

First, the concept of reducing overall needs in energy demand, or "sufficiency," rather than merely improving efficiency, is not yet fully integrated into EU legislation (Paul Messad, 2023). Second, while behavioural change is recognized as key to future European energy policy, there is still a need for better incorporation of behavioural science to influence energy use habits—both in daily life and in major decisions that affect energy consumption (e.g., housing investments, mobility choices) (Klöckner et al., 2024). Third, closely related to behavioural change, the increasing share of renewable energy in the mix necessitates a demand that can adjust smoothly to supply fluctuations, requiring a bridge between user behaviour and new technologies. Policies, therefore, need to be more adaptable to rapidly evolving technologies in energy efficiency and renewable energy (Eerma et al., 2022). Fourth, as the energy transition progresses, it is increasingly important to better integrate circular economy principles into energy efficiency policies to improve cost-efficiency and ensure security of supply (Kandpal et al., 2024). Fifth, and inherent to the implementation of EDM policies, there is a need for more structural approaches to addressing energy poverty (both winter and summer), considering long-term solutions rather than just short-term relief (J. Li, 2023). Recent adjustments in the EED recast are moving in this direction, with a full article now (Article 24) recognizing the need to prioritize energy efficiency among vulnerable consumers.

Finally, it is crucial to ensure that public funds finance real energy savings rather than actions with uncertain or merely potential results (Chlond et al., 2023; Rohde et al., 2015). This requires effective targeting and continuous monitoring to ensure the efficient use of public resources.

Recent findings from the Scientific Climate Advisory group echo these conclusions, emphasizing the need for EU policies to broaden their scope and adopt more end-user centric approaches. The group recommends: “EU policies should incentivise more vigorously the reduction of energy and material demand (in mobility, housing, material use and diets), both through efficiency improvements and behavioural changes. To enable this, policies should establish structures and introduce end-use innovations which increase the quality, affordability and convenience of lower-emissions products and services” (European Scientific Advisory Board on Climate Change, 2023).

This recommendation underscores the importance of not only improving technological efficiency but also addressing consumer behaviour and preferences. It suggests that future EU legislation should place greater emphasis on demand-side management and create an environment that makes choices compatible with climate and environmental objective more attractive and accessible to end-users.

A final idea to consider is the concept of **downsizing** or **downshifting** policies.

Recent regulatory initiatives like the *Critical Raw Materials Act*, the *Ecodesign for sustainable products* or the *Right to Repair* are already anticipating the future importance of these approaches for the European market. Moreover, other existing policies, like the EED and the EPBD, have been recently updated to include partially these elements. These policies aim to generate final value through alternative, more sustainable means.

Downsizing policies focus on reducing the physical scale of consumption. These policies encourage the use of smaller, more energy efficient products, such as compact appliances and vehicles, reducing excessive packaging to minimize resource consumption and waste, or promoting denser urban developments to cut down on transportation needs and energy-intensive infrastructure. Personal carbon allowances (Fuso Nerini et al., 2021) (whose implementation is still under discussion (*Individual Responsibility, or Responsibility of Individuals? A Debate on Personal Carbon Allowances*, 2023)) could also fit in this group. Downshifting policies, on the other hand, focus on reducing the overall level of consumption and include public campaigns to educate consumers on the benefits of reduced consumption and practical tips for adopting sustainable lifestyles. They might also involve economic incentives, such as tax breaks or subsidies for energy efficient products and services, and the promotion of sharing economies like car-sharing schemes. Even other existing policies, like the EED and the EPBD, have been recently updated to include partially these elements.

Together, downsizing, and downshifting policies can contribute to create a more resource-efficient society by influencing consumer behaviour and modifying our consumption patterns. Although the implementation of these policies is still in its early stages, a growing body of research is suggesting that they hold significant promise not only for achieving environmental goals but also for enhancing overall well-being and comfort within society (Bertoldi, 2022; Sandberg, 2021; Vita et al., 2019). However, the successful implementation of these policies presents challenges, as they rely heavily on active public engagement and a shift away from the traditional focus on technological solutions alone for demand reduction. The approach requires the collaboration of both public and private actors to fundamentally change societal energy needs, moving from actions that encourage a more rational use of energy within the existing socio-technical system to those that aim to reshape the system itself to reduce overall energy demand. A successful implementation strategy could involve a progressive approach, with short-term and long-term actions. In the short term, efforts could focus on influencing behaviour within the existing socio-technical environment through campaigns, nudging for demand flexibility, promoting downsizing, and avoiding unnecessary upsizing. Over the medium to long term, actions might include transforming the building stock to be more energy efficient and integrated with the energy system, improving urban planning, and investing in infrastructure changes, such as expanding railway networks. Ultimately, these policies recognize the crucial role of people in the transition to a more sustainable future, emphasizing that technological advancements alone are not sufficient to achieve significant demand reduction.

### 2.3.4 Examples of historical energy policy contexts in EU Member States and the role of EU legislation

While the preceding sections have explored how historical disruptions in energy supply have served as catalysts for policy reform on EDM, highlighting their essential role in shaping the future of both energy systems and society, the following paragraphs dig into specific examples from four European Union member states: France, Sweden, Italy, and Austria. These national responses provide valuable insights into the early efforts to pioneer EDM implementation and examine the readiness of EU countries to adopt such measures in the future.

The case studies illustrate the various strategies employed to address energy security concerns and reduce dependence on external sources by integrating EDM policies. The discussion also highlights the role of EU legislation in shaping and harmonizing these national initiatives.

### *National historical energy trends*

Despite its large economy, France faced significant energy dependency at the beginning of the 70s, with energy imports still accounting for 3.8% of its GDP in 1979 (Debonneuil, 1979). Following the 1973 oil shock and the subsequent concerns about energy supply, the government of Prime Minister Pierre Messmer unveiled a plan in 1974 to reduce France's dependence on oil by building several nuclear reactors. This initiative resulted in the commissioning of the first pressurized water reactor in Fessenheim three years later, followed by the construction of 54 reactors more. All of France's 900 MWe reactors were commissioned between the late 1970s and early 1980s and still allow France to generate approximately 70% of its electricity from nuclear energy in 2023 (World Nuclear Association, 2023). These investments resulted in a remarkable 27% reduction in $CO_2$ emissions over seven years (between 1980-1987), positioning France among the leading nations in Europe for low $CO_2$ emissions per capita (Jean-Baptiste, 2003). Since then, ongoing efforts have been made to promote energy independence, with the dependency rate decreasing from 50.6% in 2009 to 44.5% in 2020, marking a substantial 6.1% reduction (Eurostat, 2022; Statista, 2022). However, France still heavily relies on imports for oil (98% imported) and gas (99%), a trend also observed in the broader European Union, albeit to a lesser extent. Yet, the need to rely on gas imports from countries other than Russia (primarily LNG from the US) due to the war in Ukraine has escalated France’s net energy bill from €44 billion in 2019 to €116 billion in 2022 (Energy Transition Ministry data, 2020). Currently, France continues to prioritize nuclear energy production, with ongoing investments in the construction of new production plants. However, the country is also exploring increased diversification (for an explanation on why diversification is important, refer to Box 2). Moreover, France's commitments to the EU agenda, as outlined in the NECP, encompass diversification of energy sources, with a greater emphasis on biomass utilization. Strong investments in energy efficiency are prioritized, alongside potential plans to elevate ambitions regarding the share of renewable energy sources. Additionally, there is a strong commitment to technological advancement, particularly in the development of small nuclear reactors (SMRs), as part of the long-term vision extending to 2050.

### *Policies and legislation*

Energy demand management has been integral to French energy policy since the 1973 oil shock when rising prices and energy bills led to social discontent. The national strategy to address energy dependency was to rely on the construction of nuclear power plants. This effort was accompanied by a campaign with the slogan "*In France, we don't have oil, but we have ideas*," emphasizing the importance of innovation and creativity in the face of the energy crisis. Short-term legislative measures were implemented to encourage energy savings, such as speed limits on roads, the end of late-night television broadcasts, restrictions on outdoor lighting, heating caps in buildings or even the daylight-saving time. Following the second oil crisis, a new campaign called "La chasse au gaspi" (1979) was launched to promote fuel efficiency. While these efforts initially curbed energy consumption growth, the subsequent witnessed overall increases in consumption. The 1980s, characterized by economic expansion, lifestyle changes, and the emergence of energy-intensive technologies, counteracted conservation efforts. Besides, declining oil prices and the abundant supply of nuclear power reduced incentives for further energy savings (Kadoshin et al., 2000).

*Since then, the promotion of energy savings has been gaining increased attention with the implementation of various policies (Jestin-Fleury & Pinto, 1988). At the turn of the millennium, France's energy policy* *shifted dramatically (see*

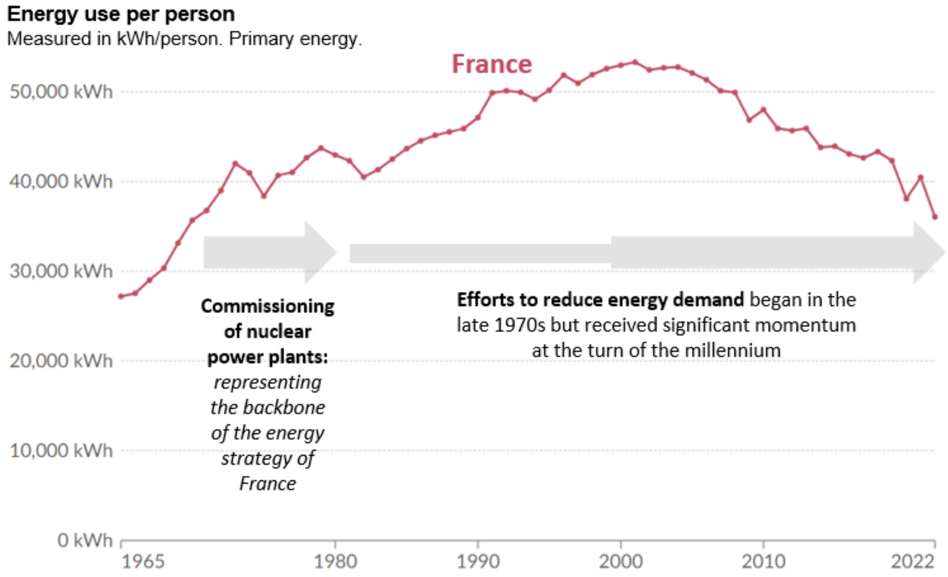


Figure 3). The Law of February 10, 2000, aligned with EU directives, liberalized the electricity market, opening production and marketing to competition. This competition spurred energy providers to focus on reducing energy consumption as a selling point, leading to increased promotions and initiatives for consumer savings. In parallel, public initiatives like the "*Espaces Info Energie (EIE)*" network, established in 2001, provided households with personalized energy reduction advice. This two-pronged approach, driven by both market forces and public policy, has significantly increased consumer awareness and actions towards energy savings. Additionally, the energy efficiency certificates program or "*Certificats des Économies d'Énergie (CEE)*", launched in 2004, requires energy suppliers to achieve government-mandated savings targets, with funds allocated to improve energy efficiency in residential and tertiary buildings (IEA, 2019). This program functions as a market-based mechanism to incentivize energy savings and has been successful in engaging energy suppliers and encouraging them to invest in energy efficiency measures, such as insulation, HVAC upgrades, and lighting retrofits. Beyond its core function, the program has funded national projects aiming at fighting energy poverty and promoting energy-saving practices among citizens. Under the Grenelle 2 law (Legifrance, 2012), a portion of these savings is directed towards energy-vulnerable households, with a focus on promoting information dissemination, training, and innovation incentives. France was also among the first EU countries to establish Energy Efficiency Obligation Schemes (EEOS) programs, albeit with low savings targets initially, serving as a trial period for obligated parties to adapt and establish relationships with stakeholders for effective implementation (Fawcett et al., 2019). Moreover, the concept of "*sobriété énergétique*" (energy sufficiency) (Selma Mahfouz, 2023) has gained quick traction in the country, leading to pioneer regulations aimed at reducing overall energy consumption. Recent measures under the "Loi climat" (Légifrance, 2021) include the banning of short plane trips between connected cities and efforts to minimize light pollution in heritage sites. Currently, the National Low-Carbon Strategy (SNBC), outlines how the transition to carbon neutrality requires mobilizing a range of complementary measures, combining technologies and changes in consumption patterns. And yet, recent interventions have shown that focusing mainly on short-term relief risks hindering long-term investments crucial for the low-carbon transition and future resilience (Pisani-Ferry, 2023). The SNBC aims to reduce carbon emissions from industrial and agricultural processes, shift consumption patterns, and sequester carbon through natural carbon sinks and technologies. The goal is to achieve carbon neutrality by 2050 (Direction générale du trésor, 2023). France's climate policies hold weight in the EU. They pushed for nuclear power's recognition as a clean energy source and are pioneers in sufficiency policies. France's forward-thinking extends to the Ecodesign and the Energy Labeling Directive. They're

among the first EU countries to implement a reparability index since 2020 (Ministère de la transition écologique et de la cohésion des territoires, 2024), a move currently supported by a recent European regulation legislation.

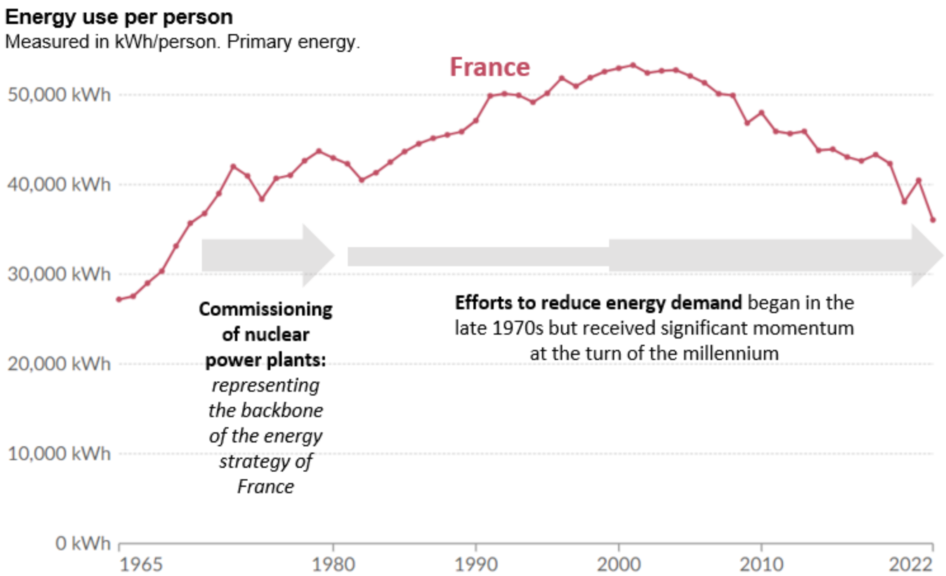


*Figure 3:Primary energy use per person (using the substitution method) in France between 1965 and 2022.*

***Source:*** Adapted from U.S. Energy Information Administration (2023), Energy Institute - Statistical Review of World Energy (2023) – Published online at OurWorldInData.org

***National historical energy trends***

In line with the trend observed in the majority of EU countries, Sweden has experienced a continual rise in dependence on fossil fuels over the past decades. Historically, Sweden's energy sector has been characterized by a strong emphasis on public ownership and control, with state-owned entities like Vattenfall playing a central role in electricity generation and distribution. At the beginning of the 1970s, Sweden relied on an oil-based energy system. However, in absolute terms, both energy consumption and pollution increased until 1970. After this date, energy consumption stabilized, and pollutant emissions declined, leading to a reduction in environmental stress and an increased energy independency (Kander & Lindmark, 2004). Two main factors contributed to this change in trends. On one hand, the addition of 12 nuclear reactors to the grid between the 1970s and 1985. On the other, the progressive installation of district heating lines, mainly driven by political authorities (Wickman, 1988). The liberalization of the energy market in the 1990s, prompted by European regulation, brought about significant changes, including the introduction of competition and the opening up of opportunities for private actors (see Högselius, 2009). However, traditional robust regulatory mechanisms naturally provided larger stakeholders in the energy market with opportunities to take actions in both political and business spheres. This resulted in a self-reinforcing process characterized by substantial interdependency between the political and business arenas (Högselius & Kaijser, 2010). The approval of the carbon tax in 1991 is a good example of a successful policy mechanism under these conditions. The scheme led to higher fuel prices, which in turn incentivized the adoption of energy-efficient technologies and practices. This resulted in a substantial decrease in energy use for heating and an overall improvement in energy efficiency in the residential sector (Schipper et al., 1993). Yet, thanks to its abundant domestic production of biofuels, alongside nuclear and hydropower resources, Sweden has overall maintained low energy prices when compared to other countries (Renders, Dauwe, Ahlgren, Young, Jozwicka, 2018). In recent years, newer efforts to optimize energy use per capita included implementing green taxes on oil (Millot et al., 2020a), programs to stimulate electricity savings (Blomqvist et al., 2022), along with a focus on efficiency systems focussed on new technologies like wind (Meyer, 2007) and heat pumps (Millot et al., 2020a). Additionally, substantial investments continue in district heating, exploring ways to leverage the flexibility of this technology (Fernqvist et al., 2023). Biomass use was also significantly boosted, increasing by nearly 170% from 1983 to 2016 (Millot et al., 2020b). Recently, energy targets have shifted from achieving 100% renewable electricity by 2045 to achieving 100% fossil fuel-free electricity by 2045, reflecting the role of nuclear energy in the future (lorence Jones, 2023). Aligned with the EU's net-zero objective, the country already generates 98% of its electricity through hydropower, nuclear, and other renewable sources, although it still relies heavily on fossil fuels for transportation (Wikipedia, 2024). See **Error! Reference source not found.** for overview of primary energy use per capita.

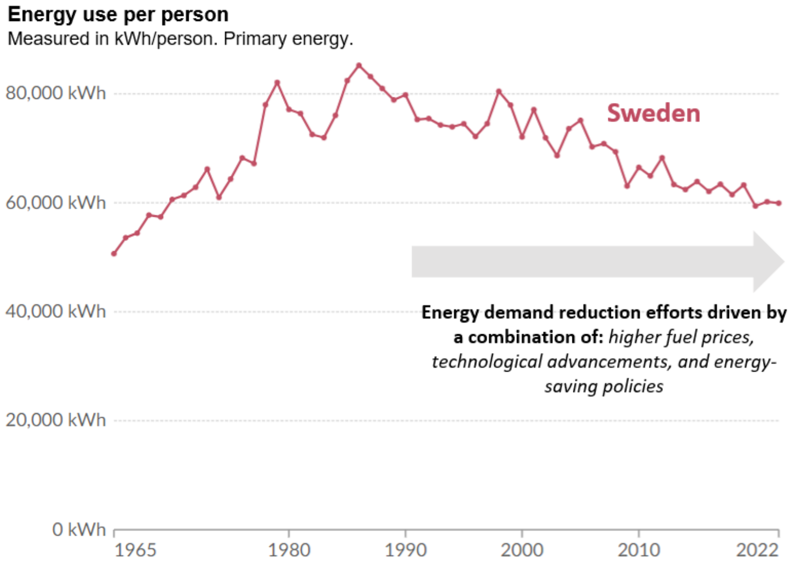


*Figure 4: Primary energy use per person (using the substitution method) in Sweden between 1965 and 2022.*

***Source:*** Adapted from U.S. Energy Information Administration (2023), Energy Institute - Statistical Review of World Energy (2023) – Published online at OurWorldInData.org

### *Policies and legislation*

Following the oil crisis, Sweden took measures to further reduce its vulnerability to shocks stemming from fluctuations in oil prices in the energy market. During the 1970s and 1980s, Swedish oil imports were redirected from politically unstable Middle Eastern countries to North Sea producers. This strategic shift, coupled with the adoption of diversified energy provision strategies, including reliance on nuclear energy and biomass market generation utilizing forest resources (which had been abandoned due to cheap fossil fuel imports), as well as the development of national district heating mechanisms, significantly strengthened the country's energy security (Millot et al., 2020b; Wickman, 1988). Energy dependency[3] has been therefore declining over time passing from 39.3% in 2000 to 33.5% in 2020 (-5.8%) (Eurostat, 2022; Statista, 2022). All these infrastructural efforts were complemented by a series of policy mechanisms aimed at promoting a significant bias towards oil conservation. Both the "*Teknikupphandling*" and the "*Vattenfall's Uppdrag*" were good examples of these efforts aimed at streamlining technology procurement and enhance industrial competitiveness by modernizing energy infrastructure. These policies progressively gained strength as the country positioned itself as an environmental leader. Notably, Sweden hosted the Stockholm Conference in 1972, a pivotal event that marked a turning point in the global recognition of environmental issues as international concerns (Millot et al., 2020b). In this line, in 1991, Sweden was pioneer to implement a carbon tax that encourages individuals and businesses to decrease their carbon footprint by discouraging the use of high-emission fuels and promoting cleaner alternatives. Revenue generated from the carbon tax is frequently reinvested into renewable energy projects, fostering sustainability initiatives. Notably, the carbon

[3]) Defined as the ratio between net imports and gross available energy indicates the ability of a country or a region to meet all its energy needs.

tax has facilitated the expansion of biomass for district heating generation, optimizing biomass extraction efficiency and plant operations (Sterner, 2020). By 2014, 93% of all dwellings in multi-family residential houses were connected to district heating, which also delivers heat to service sector buildings, single-family residential houses, and industries (Werner, 2017). Importantly, the tax has also promoted private investments in energy innovation leading to efficiency (Cheng et al., 2021). A pivotal moment arrived with the introduction of the Electricity Certificate System in 2003, incentivizing renewable energy production through certification. This initiative spurred investments in wind, solar, and biomass energy, contributing to Sweden's reputation as a leader in renewable energy adoption and enhancing its diversified energy strategy (See Box 1) (Swedish Energy Agency, 2023). Another significant initiative in Sweden's energy policy has been the establishment of local energy advising (LEA) offices, serving as subsidized entities to enhance household energy efficiency since the 1970s (Kjeang et al., 2017). Various EU and national policies has influenced domestic energy efficiency in Sweden in the last years, encompassing directives like the EPBD, the EED, other national building standards such as BFS 2015:3 and Near-Zero building and passive house programs (Renders, Dauwe, Ahlgren, Young, Jozwicka, 2018).

**Box 1 France and Sweden: comparison of different approaches and advantage of the Swedish more diversified set of actions.**

Following the oil crisis in the late 1960s and early 1970s, the energy policies of France and Sweden took divergent paths, reflecting their differing approaches to energy transition and explaining long term trend in energy use. While both countries initially relied on a mix of oil, hydropower, and nuclear programs, Sweden implemented a more diversified and balanced set of measures in response to the crisis. This included the development of district heating (DH) fueled by biomass and heat recovery, alongside nuclear power for electricity generation. In contrast, France primarily focused on nuclear power first, emphasizing the development of electricity, and gas imports later despite similar renewable energy resources being available. Sweden's introduction of a carbon tax further facilitated emission reduction, particularly in the building and power sectors. France's centralized planning approach limited its adaptability, with energy investments largely planned at the national level, missing potential development of local resources promoted by municipalities' energy planning. Additionally, France's predominant production model, even if derived from low-carbon sources, has traditionally operated under the principle that demand should dictate supply, resulting in the use of inefficient systems like electric heating. Despite these differences, both countries benefited from strong political support for their respective energy policies, driving successful transitions. However, challenges remain, particularly in the transport sector, where neither country has fully transitioned to low-carbon alternatives. Regarding France, it is worth noting that energy efficiency is not always at the forefront, as seen during the COVID-19 pandemic when high energy demand was observed due to fixed prices and the use of electric heating. Although electric heating was once an efficient heating method, it is less efficient when considering the efficiency of electricity production. For Sweden, while the country has taken a diversification and low-carbon fuels approach, energy demand per household remains high compared to other countries, effects not always due to climate conditions (Schipper et al., 1993). This inconsistency highlights the need for continued efforts to reduce energy demand and improve energy efficiency in Sweden (Millot et al., 2020).

***National historical energy trends***

*Italy's energy consumption trends have been influenced by changes in government, supply, policies, and strategies. Historically, Italy relied heavily on imported fossil fuels but has diversified its energy sources and invested in renewables for enhanced energy security. During the Mattei era from 1946 to 1963, there was a notable shift towards energy autonomy, marked by increased consumption of hydrocarbons like crude oil and natural gas. However, this period did not see significant initiatives aimed at reducing energy demand* (Pozzi, 2010)*. After the 1970s oil crisis, Italy implemented significant energy conservation efforts. ENI advanced these initiatives, focusing on reducing energy demand through measures such as promoting energy efficiency in industries and buildings, leading to a decline in energy consumption during the early 1980s* (Di Nucci & Russolillo, 2019; Labbate, 2014b). *Partly as a reaction to the Chernobyl disaster, the decision to halt Italy's nuclear program in 1987 reflected growing public concerns about safety and environmental risks associated with nuclear energy, as Italians took part in a referendum voting against the expansion of nuclear energy* (World Nuclear Association, 2024)*. Instead, the country shifted its focus towards renewable energy sources, which played a role in reducing energy demand and increasing energy security. Between 1985 and 2005, Italy experienced periods of economic growth which led to increased energy consumption. This rise was driven by higher industrial activity, increased household energy use, and expanded transportation needs. Despite ongoing energy efficiency measures, the overall energy demand grew due to these economic factors* (International Energy Agency, 2023a). The country's energy intensity has decreased by 15% from 2005 to 2021, indicating a move from industrial to service sectors and also improvements in energy efficiency. Despite recent improvements, energy dependency in Italy remains high, decreasing from 86.5% in 2000 to 73.5% in 2020 (-13% decrease) (Eurostat, 2022; Statista, 2022). *Efforts to increase the use of natural gas and renewables, coupled with a decrease in coal and oil consumption, have contributed to a decline in energy demand and greenhouse gas emissions.* A significant aspect of Italy's energy landscape is its reliance on fossil fuel imports from Russia (in particular, natural gas), which accounted for one third of total energy supply of fossil fuels in 2021. As a result, Italy diversified its natural gas supply routes and sources to reduce dependency on Russian gas. Investments were made in liquefied natural gas infrastructure and pipeline interconnections, which allowed for greater flexibility and security in gas supplies. This included the development of natural gas terminals and the enhancement of pipeline capacities to facilitate gas imports from various countries (International Energy Agency, 2023a). See Figure 5 for overview of primary energy use per capita in the country.

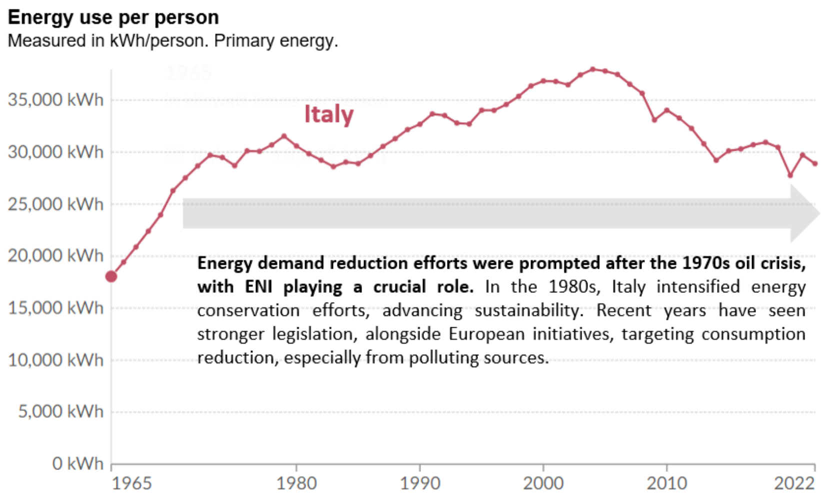


*Figure 5:Primary energy use per person (using the substitution method) in Italy between 1965 and 2022.*

***Source:*** Adapted from U.S. Energy Information Administration (2023), Energy Institute - Statistical Review of World Energy (2023) – Published online at OurWorldInData.org

### *Policies and legislation*

*Italy has implemented comprehensive policies and legislation aimed at addressing energy demand reduction and promoting energy efficiency as part of sustainable energy management. Recognizing the importance of optimizing energy use, the country aims to fortify energy security and reduce consumer costs. Italy prioritizes enhancing energy efficiency in both residential and commercial buildings, and its efforts have led to a 15% decline in energy intensity between 2005 and 2021* (International Energy Agency, 2023a)*. In response to the 1973 oil crisis, Italy indeed began to focus on energy efficiency to reduce dependence on imported oil. The government implemented policies aimed at improving energy efficiency in industrial processes and promoting energy conservation measures across various sectors* (Schramm, 2024)*. A significant policy in this area is the White Certificates Scheme, introduced in 2001 and operational since 2005, which promotes energy efficiency primarily in the industrial sector but also in households. This scheme, featuring rising targets and covering various sectors, is a model for monitoring and verification, allowing for the exchange of certificates among obliged and voluntary parties. DSOs can recover 60% of the target over the next two years, improving insulation to mitigate heat loss in winter and heat gain in summer* (Dario Di Santo & Livio De Chicchis, 2019)*. Italy's First National Energy Plan in 1981 set objectives for renewable energy development and emphasized energy efficiency in buildings, industrial processes, and transportation. The Thermal Regulation Law of 1982 laid the foundation for regulatory measures and financial incentives for energy efficiency and renewable energy. The Energy Services Directive of 2006 further promoted the use of ESCOs to implement energy efficiency projects. In the industrial sector, Italy incentivizes businesses through tax breaks and awareness campaigns to adopt energy-efficient technologies and practices. The country is also committed to reducing energy consumption in transportation, promoting electric vehicles, enhancing public transport infrastructure, and investing in cleaner fuel alternatives. Since 2017, Italy has promoted EV adoption and infrastructure, with plans to install 21,000 charging stations by 2026 and a fleet of 30,000 EVs by 2030. Solar power has been strongly supported since the 1970s, with significant incentives introduced in the 2000s through the Conto Energia program. This program provided substantial support for solar energy adoption, contributing to the growth of solar* power installations across the country. In 2022, Italy introduced new simplification rules for renewable energy sources (ENI, 2022a). Wind energy has been expanding since the 1990s, and 5GW of offshore wind projects are planned through auctions between 2023 and 2026 (ENI, 2022b). Italy also sees potential in geothermal energy, being a historic producer of geothermal electricity. Biofuels have been mandated since 2014, with increasing requirements for gas and diesel to contain biofuel (ETIP, 2023).

Italy aims to phase out its dependence on Russian gas by 2025, enhancing its energy security and aligning with its goal of achieving carbon neutrality by 2050 (Pickering et al., 2022). Addressing energy poverty is also a priority, with policy measures such as social bonuses for electricity and gas and tax deductions on electricity and heating fuel. Italy's energy policies and efforts are outlined in its National Energy and Climate Plan for 2030, positioning the country to meet its emissions reduction and energy efficiency targets (International Energy Agency, 2023a).

## AUSTRIA

***National historical energy trends***

*From 1950 to 1980, Austria developed substantial electricity capacity through run-of-river and pumped-storage plants, establishing a lasting tradition of hydropower. This tradition persists as Austria integrates renewables and gas into its energy mix* (IEA, 2020)*, resulting in a regionalized distribution of energy infrastructure, particularly with a prevalence of hydropower and thermal power stations in the electricity grid* (Wagner et al., 2015)*. In the 1970s, the Grundstoffindustrie* (Fahrnberger et al., 2021) *(basic materials industry) in Austria was a major consumer of energy, with sectors like iron and steel, paper and printing, stones, earth, glass, and the chemical industry utilizing a significant portion of the country's final energy. During this period, there was a notable shift in Austria's industrial landscape, particularly regarding energy demand reduction. While steel production remained relatively stable, the aluminium industry experienced a collapse in 1990, prompting a transition towards aluminium processing rather than primary production. This shift underscored the importance of energy efficiency as industries sought to reduce their energy consumption. By the 1980s, the Grundstoffindustrie in Austria consumed half of the total end energy of the industrial sector. Although steel production remained steady, there was a decline observed from the 1990s onward, signalling potential changes in industrial activities and energy consumption patterns. In the 1980s there was a dominance of the challenges of balancing industrial energy needs with sustainability concerns. The transition from the energy-intensive secondary sector to the less energy-intensive tertiary sector in the 1990s contributed to a stagnation in industrial energy consumption. This shift towards the tertiary sector, characterized by services and less energy-intensive activities, influenced overall energy consumption patterns in the country. The 1990s marked a significant period of transition in Austria's industrial energy consumption, with a gradual shift towards sectors with lower energy intensity, impacting energy policy and sustainability efforts. Austria's energy policy evolved from crisis interventions to long-term planning approaches, recognizing the need for a comprehensive and integrated approach to address energy consumption patterns and sustainability considerations. As of November 2021, Austria had made significant strides in renewable energy, with wind, solar, biomass, hydro, and energy from waste contributing to the country's renewable energy portfolio. The government aims to achieve 100% renewable electricity by 2030, necessitating a substantial escalation in renewable energy generation. Austria is now committed ensuring universal access to electricity, with a 100% electricity access rate maintained from 1990 to 2021. In line with its renewable energy ambitions, Austria aims for carbon neutrality by 2040, excluding nuclear power, and focusing on decarbonizing the heat and transport sectors.* See Figure 5 for overview of primary energy use per capita in the country.

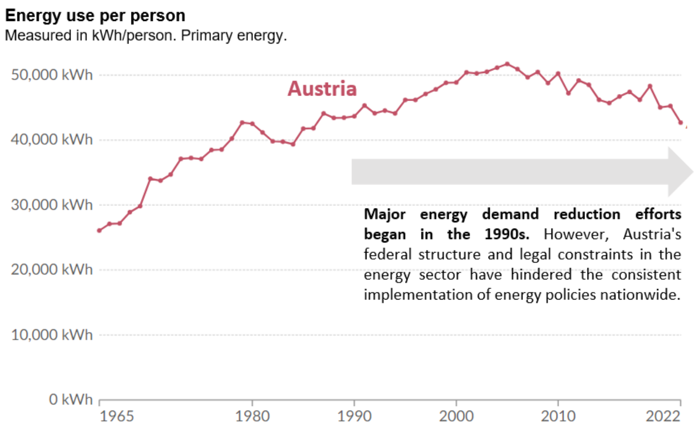


*Figure 6: Primary energy use per person (using the substitution method) in Austria between 1965 and 2022.*

***Source:*** Adapted from U.S. Energy Information Administration (2023), Energy Institute - Statistical Review of World Energy (2023) – Published online at OurWorldInData.org

***Policies and legislation***

*Austria's energy policy implementation has been marked by pivotal phases, each reflecting broader socio-political contexts and technological advancements. These phases encompassed corporatist expansion, heightened politicization, and subsequent stabilization. The Bundesministerium für Handel, Gewerbe und Industrie played a central role in guiding energy policy, navigating through phases of corporatist growth and increased politicization. In the phase of corporatist expansion from 1970 to 1980, Austria's energy policy was largely a response to the 1970s oil crises, prioritizing energy security and economic stability. During this period, the conservative ÖVP and the social democratic SPÖ dominated the political landscape, with significant input from social partners and scientific advisors. The policy focus was predominantly on increasing energy production to ensure energy security, overshadowing demand-side measures* (Haas et al., 2017)*. Initial steps towards energy efficiency included promoting less energy-intensive technologies and energy-saving practices, but these were secondary to production increases. The federal structure created fragmentation in policy implementation, limiting the effectiveness of early energy efficiency efforts. This phase is characterized by a steady increase in energy use per person from 1965 to 1980, reflecting the focus on expanding energy production to meet growing demand* (IEA, 2020)*. The subsequent phase of heightened politicization from 1980 to 1990 saw the emergence of new social movements and increased environmental consciousness. Political parties such as the ÖVP, SPÖ, and FPÖ, along with civil society movements and environmental activists, played crucial roles in shaping energy policy. This period was marked by increased political debates and policy shifts, with a stronger emphasis on energy efficiency and environmental protection* (ICLG, 2023)*. Policies for energy conservation were expanded, including incentives for energy-efficient appliances and industrial processes. However, governance issues, such as regional disparities and intense political debates, hindered the uniform implementation of demand-side measures. The consumption trend during this phase shows fluctuations in energy use per person, indicating the initial impact of energy efficiency measures amidst ongoing production increases. From the 1990s onwards, Austria's energy policy focused on stabilization and modernization in the face of global climate challenges and energy security concerns. There was a marked shift towards reducing energy demand, with significant national programs for energy conservation and efficiency improvements in industrial and residential sectors* (IEA, 2020)*. During the 1990s, major efforts to reduce energy demand included national programs for energy conservation. The 2000s saw stricter energy efficiency standards for buildings and* *appliances, along with support for renewable energy technologies. In the 2010s, national energy efficiency plans were enhanced, smart grid technologies were widely adopted, and public awareness campaigns on energy conservation increased. The 2020s continued this focus, with a commitment to achieving 100% renewable electricity by 2030 and carbon neutrality by 2040, further tightening energy efficiency regulations, and deploying large-scale renewable energy projects and energy-saving initiatives* (Obinger et al., 2010). *A significant recent policy is the implementation of the National Carbon Market system for buildings and transport, aimed at regulating and reducing emissions through market-based mechanisms* (Austrian Federal Chancellery, 2020). *Despite these advancements, the federal structure and legal constraints continue to create policy fragmentation and regional disparities in implementation. The consumption trend from 1990 to the present shows a gradual decline in energy use per person, reflecting the increased focus on energy efficiency and demand reduction policies. Major energy demand reduction efforts began in the 1990s, as highlighted in the image. Austria's current energy strategy emphasizes reducing energy demand and prioritizes renewable energy supply, efficient electricity distribution, and improved energy efficiency. Key objectives include aiming for 100% renewable electricity supply by 2030, targeting carbon neutrality by 2040, and promoting initiatives to enhance energy efficiency and reduce greenhouse gas emissions. Demand-side management, although historically under-prioritized, is increasingly recognized and integrated into national policy frameworks.*

### 2.3.5 Sector-specific variations in energy consumption trends

*Whether solely due to policy schemes or not, data shows a modest decline in energy consumption per person in the EU, though the impacts vary significantly across MS and sectors* (Di Berardino et al., 2021). *Climate-corrected data on final energy consumption in the European Union from 2000 to 2022 confirms this trend. Starting at almost 925 Mtoe in 2000, energy consumption initially rose by 22.6% (209 Mtoe) due to heightened economic and social activities, reflecting changes in industry, services, transport, and household consumption. Structural changes, such as sectoral shifts and improved transport efficiency, slightly reduced consumption by 1.6% (15 Mtoe). Notably,* ***technical energy savings measures****, including improved efficiency in appliances, buildings, and industrial processes, contributed to a substantial 25.9% reduction (240 Mtoe). Additional factors, such as behavioural changes, labour productivity, and inefficiencies, added 4% (37 Mtoe) to consumption. Overall, despite significant increases driven by economic activity, technical savings helped bring final energy consumption down to 916 Mtoe in 2022, a 1% decrease compared to 2000 levels* (seeFigure 7).

*Sectoral analysis shows that industry has seen the most significant energy reduction. Corrected final consumption in the industry sector dropped by 17.4%, from 293 Mtoe in 2000 to 242 Mtoe in 2022. Agriculture saw a slight decrease of 1.4%, from 28.3 Mtoe to 27.9 Mtoe. In contrast, the services sector increased by 9.7%, from 113 Mtoe to 124 Mtoe, while transport consumption rose by 8%, from 263 Mtoe to 284 Mtoe (*Source**:** Odysee-Mure).

The sharp decline in production capacity within European industry, particularly over the last few decades, has been further exacerbated by restricted access to inexpensive Russian gas. According to data *from the International Energy Agency (IEA), a significant drop in electricity consumption by industries in 2022 (5.8%) and an even steeper decline in 2023 (6%)* (Electricity Market Report, 2023) was observed*. Energy-intensive sectors like aluminium (12% decrease), steel (10% decrease), paper (6% decrease), and chemicals (5% decrease) were particularly impacted* (Electricity Market Report, 2023)*. These trends have been contributing and continue to contribute to the noticeable decrease in overall energy consumption across most EU countries.*

*This data highlights the importance of considering sector-specific dynamics when designing policies aimed at reducing energy consumption, as reductions are not evenly distributed across the economy.*

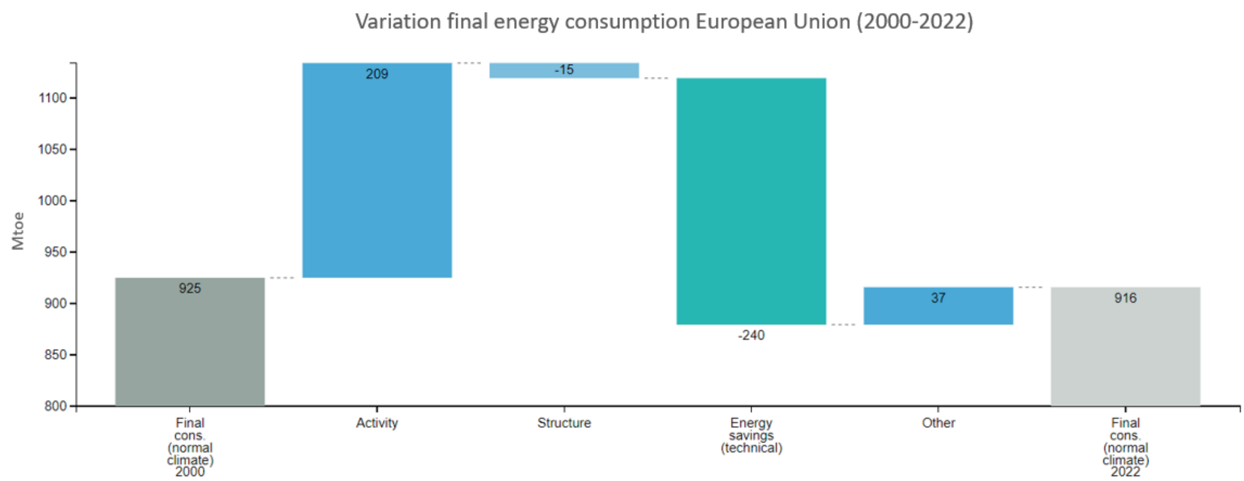


*Figure 7: Climate adjusted variations in the European Union between 2000 and 2022, measured in Million tonnes of oil equivalent (Mtoe).*

**Source:** Odysee-Mure decomposition analysis tool https://www.indicators.odyssee-mure.eu/decomposition.html.

## 2.4 Economic considerations regarding energy demand management

### 2.4.1 Economic growth and energy demand management.

Economic factors have been instrumental in shaping energy management policies (Economidou et al., 2020; Sorrell, 2015). The recent energy crisis in Europe, triggered by the Russian invasion of Ukraine, underscored this relationship, with soaring energy prices prompting significant demand response measures (Atradius, 2024). Notably, household gas consumption decreased by nearly 20% in 2023 compared to pre-crisis levels, followed by reductions in industry and power sectors (Atradius, 2024).

However, the historical correlation between economic growth and energy consumption has often overshadowed the potential of energy efficiency as a driver of economic benefits (Sorrell, 2015). This misconception has hindered the implementation of effective EDM policies. While economic growth remains a priority, research indicates a decoupling of economic growth and energy use is feasible, especially in developed economies (Moriarty & Honnery, 2023). To reconcile economic objectives with energy demand reduction, a multifaceted approach is necessary. This involves addressing economic barriers to energy efficiency, such as regulatory hurdles and financial constraints, while simultaneously exploring the economic opportunities presented by demand reduction, including enhanced energy security and productivity gains. In this context, price mechanism policies have been instrumental in programs aimed at reducing (Dutta & Mitra, 2017) or delaying energy consumption (Dutta & Mitra, 2017; Moriarty & Honnery, 2023).

### 2.4.2 Role of energy prices in energy demand management policies and strategies

Energy pricing (and energy price-based instrument at large) in policy mix significantly influences demand management strategies and their effectiveness (Stechemesser et al., 2024). Recent research has emphasized the importance of domestic energy prices in maintaining energy security (Rabbi et al., 2022), regulating demand growth (Moriarty & Honnery, 2023), and promoting investments in energy resource development (López González & Garcia Rendon, 2022). Numerous factors drive interest in EDM policies, including the need to lower energy bills, address supply challenges, reduce dependence on fossil fuels, and achieve climate goals. Technological advancements also significantly influence these policies (Cc, 2022; Della Valle & Bertoldi, 2022; International Energy Agency, 2023b).

Fluctuations in gasoline prices and their economic impacts highlight the need for understanding retail energy price shocks. In the global market environment, management of energy prices is important, with regulation of oil prices on global markets involving a complex interplay of geopolitical forces, supply and demand fundamentals, and market speculation (KPMG Germany, 2021).

Changes in energy consumption patterns and behaviour in response to increasing or spiking energy prices can be estimated by using price elasticities. These elasticities differ significantly by energy source (Jagtenberg, 2024), i.e., the demand for fossil heating fuels is more price elastic than for electricity, with long-term price elasticities being larger than short-term ones (Jagtenberg, 2024).

Table 3 below provides an overview of the bandwidths of price elasticities of energy demand. Overall, it can be noted that price elasticities for electricity are low (relatively inelastic). For most households, electricity provides a basic good that cannot be reduced drastically in the short term. In the longer term, investment in energy efficient appliances can result in energy savings. The difference between short term and long-term elasticities is more pronounced for natural gas as to reduce natural gas use for heating, for instance, the installation of a new heating system or an energy retrofit of the building is required which is asking for sufficient implementation time (Jagtenberg, 2024).

In the context of European energy policy, which aims to improve energy efficiency and transition to $CO_2$-free energy sources, it is crucial to distinguish between own-price elasticity of a fuel type[4] (energy savings), as well as and cross-price elasticity[5] (related to fuel-switching) (Jagtenberg, 2024). However, limited information is available in literature about the cross-price elasticities, suggesting a need for further research in this area.

Concerning the own-price elasticities, several factors are relevant to ensure a reliable estimation of the effects from behavioural changes. For instance, households must be aware of the prices they pay and their energy consumption as well as understand future price developments (Cappers & Todd-Blick, 2021). In addition, the elasticities vary by household income level: low-income households, already minimizing their heating consumption, have less potential for further reductions, resulting in lower price elasticity. Without additional adjustment options, they face higher costs and increased risk of energy poverty (European Energy Research Alliance, 2024), as seen in some countries EU Member States during the recent energy price rise. Conversely, higher-income households can respond to price increases by investing in energy efficiency or reducing consumption, resulting in higher long-term price elasticities (Büchs et al., 2023). Energy price elasticity for households in the EU also varies according to geographical location, specifically between rural and urban areas (Cyrek & Cyrek, 2022).

Figure 8 illustrates how targeting energy demand reduction from high-end consumers helps meet climate targets over time without significantly impacting their energy needs due to their higher elasticity of energy use. Meanwhile, increasing energy access for low-end consumers in poverty has a relatively small impact on overall energy demand reduction.

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4) Price elasticity of demand and is calculated by the percentage change in fuel consumption divided by the percentage change in the fuel's price.

5) Cross-price elasticity of demand measures how the demand for a particular fuel changes in response to the price change of another related fuel.

Table 3: *Bandwidths of price elasticity of demand estimates for electricity, heating, and fuels on household level (EU MS and other industrialized countries). Adapted from Jagtenberg et al., 2024.*

| Energy source | Price elasticity of demand short-term | Price elasticity of demand long-term |
|---|---|---|
| Electricity | -0.2 to -0.4 | -0.32 to -0.66 |
| Natural gas | -0.1 | -0.7 |
| Transport fuels | -0.1 to -0.7 | -0.3 to -0.6 |

Inertia, or resistance to change, can impede energy demand reduction efforts, but understanding the cost-effectiveness of demand reduction underscores its importance in achieving sustainable growth (Denholm et al., 2020).

### 2.4.3 Behaviour: rebound and prebound effects in EDM

A technical improvement in energy efficiency in a context of stable energy price might not automatically results in energy demand reduction. Due to rebound effects the observed demand reductions are often lower than anticipated (Sorrell et al., 2009). The rebound effect (or take-back effect) can be defined as the reduction in expected gains from an intervention that increases the efficiency of resource use, because of behavioural or other systemic responses (Renders et al., 2020). As a result, the theoretical impact an intervention could have on demand reduction, is smaller than observed. Rebound effects can be split into the direct rebound effects (occurring when a decrease in the cost of using a product results in an increased use of the product); indirect rebound effects (when a decrease in the cost of using a product results in increased use of other products or expenditure); and, macro-economic or economy-wide rebound effect (when the initial savings from an intervention, result in a stimulated demand of the whole economy (Barker et al., 2007). See for instance, the Jevons' paradox (Alcott, 2005).

Similar to price elasticities, the rebound effect of final energy use can vary according to income levels and over time (Soland, M, 2018). For example, middle-income households may experience a smaller rebound effect, as energy costs are a smaller share of their overall budget. Conversely, lower-income households often face a larger rebound effect because the financial savings from increased energy efficiency are more meaningful to them, potentially leading to increased consumption in other areas or even of energy itself, thus reducing the expected energy savings. This phenomenon, known as the prebound effect, occurs when occupants consume less energy than predicted due to behavioural or economic constraints (Sunikka-Blank & Galvin, 2012). In poorly insulated homes, for instance, residents may under-heat living spaces to conserve energy costs, resulting in consumption lower than anticipated. When energy efficiency upgrades are introduced, the actual savings may be reduced because the initial energy use baseline was already minimized due to these self-imposed limitations. Hence, targeting high-income consumers, who are more responsive to price changes, can significantly reduce energy demand and emissions without disproportionately impacting low-income households (see Figure 8). However, enhancing energy access for low-income households—allowing for a slight increase in consumption—is essential for promoting social equity, even if it has a lesser impact on overall demand (Büchs et al., 2023).

Rebound effects are most commonly measured in the context of energy efficiency improvements in households and transportation. While accurately determining the size of these effects is difficult, studies suggest that direct rebound effects for household energy use typically range from 10-30% (streamSAVE, 2022). In industrial production, direct rebound effects are around 15%, with energy-intensive industries having effects between 20-60%. Research on indirect and macroeconomic rebound effects is sparse and shows significant variability (Brockway et al., 2021).

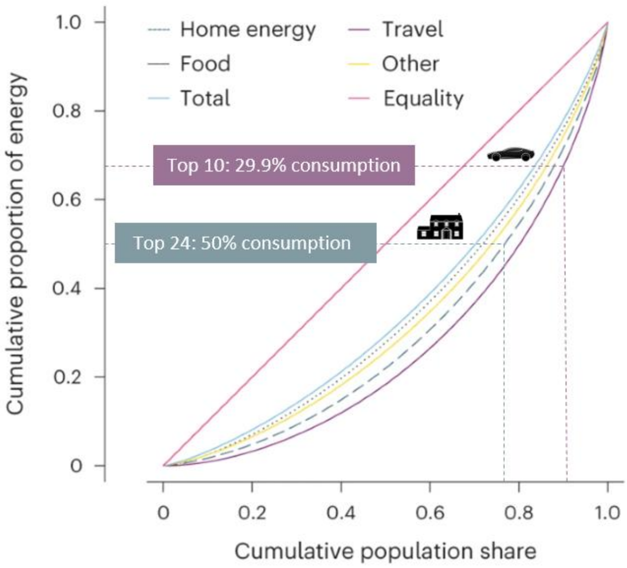



*Figure 8: Targeting high-end consumers for energy demand reduction is necessary due to their higher price elasticity, allowing significant emissions reductions without heavily impacting those in energy poverty. These consumers are more responsive to price changes and can adjust consumption more easily. Conversely, expanding energy access for low-income households has a smaller effect on overall demand but is crucial for social equity. The figure illustrates that the more curved the distribution, the greater the inequality. Notably, the top 10% consume about 29.9% of transport energy, while the top 24% use around 50% of energy in housing.*

**Source**: Adapted from Büchs et al., 2023.

### 2.4.4 Energy demand management and investment needs to achieve decarbonisation.

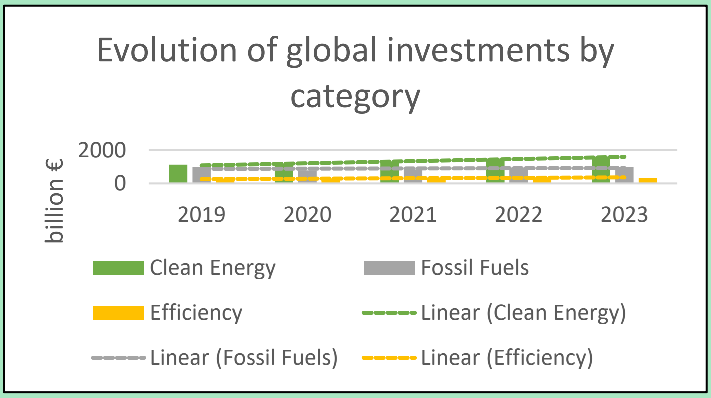
As the EU works towards its ambitious 2030 climate targets, understanding and addressing the financial and structural needs of EDM is essential. Recent analyses by the Institute for Climate Economics (I4CE) reveal that, while climate-related investments in energy, buildings, and transport systems grew by 9% in 2022 to reach €407 billion, a significant gap remains; approximately €406 billion in additional annual investments will be necessary to achieve the EU's climate goals (I4CE, 2024). This shortfall underscores the importance of balanced investment strategies that RES development with EDM efforts. This balance is crucial, as data shows that investments in RES are increasing at a much faster pace than those in EDM (see Box 2). Notably, in the French context, the Institut Rousseau advocates for a net-zero pathway centred on this balance, suggesting that combining supply-side advancements with demand-side measures can facilitate climate neutrality more effectively (Institut Rousseau, 2024). Research also highlights the value of price-based mechanisms, such as carbon pricing, which have proven effective in reducing emissions when part of a policy mix that includes energy efficiency and demand management initiatives (Stechemesser et al., 2024). Modelling scenarios, such as the CLEVER and LIFE scenarios, further reinforce the role of demand reduction, indicating that a strategic focus on sufficiency measures (e.g., the sharing economy, circular materials, sustainable mobility) can lower overall investment needs (European Commission, 2023;

Wiese et al., 2024). As the EU crafts its future strategies, this evidence points to the critical need for systemic policy designs that blend financial incentives, regulatory measures, and community-driven demand management. The following sections will explore these challenges in greater depth, including a systemic model for assessing EDM policy efficacy, aimed at enhancing the EU's capacity to meet decarbonization targets at sustainable costs.

**Box 2 Where is investment going? Renewable Energy vs. Demand Management**

According to IEA data, global investments in clean energy technology have surged in recent years. data shows a net increase of 42% between 2019 and 2023, signifying a significant acceleration in the transition towards a more sustainable energy future. Conversely, investments in fossil fuels have either decreased or stabilized during the same period, showing a downward trend. Investments in efficiency have also experienced notable increases, although the **absolute values are relatively lower compared to clean energy investments**. Regardless of the increase, the proportion of investments in efficiency relative to clean energy investments has decreased slightly, from almost 24% in 2019 to 22.6% in 2023 (see figure below). This shows that despite the well-documented cost-effectiveness of energy efficiency, investments consistently fall short of optimal levels. This gap can be attributed to several factors, including uncertainties around the measured impact of efficiency improvements. The building sector exemplifies this challenge, with energy upgrades often underperforming compared to projections (Allcott & Greenstone, 2012). While strong management practices are still vital for identifying potential savings (Cooremans & Schönenberger, 2019) , new research emphasizes the need to incorporate behavioural aspects like present bias into policy design (Lades et al., 2021). This is crucial because the current economic focus on continuous growth, coupled with rising global energy demand, can make investments in energy generation seem like a more secure option.

This holds true in Europe, despite significant policy efforts to support efficiency investments. In the recent draft NECPs submitted in 2023 reveal a disparity in MSs ambitions for renewable energy and energy efficiency. While the renewable energy targets fall short of the binding target by around 8.35%, the gap for energy efficiency is significantly wider, exceeding 50% of the 11.7% target set by the Governance regulation and the recast of the Energy Efficiency Directive (EED). Notably, only seven MSs (Denmark, Estonia, Greece, Spain, Italy, Lithuania, Luxembourg) aligned their contributions with anticipated national standards for both renewables and efficiency.



# 3 Systemic approach to monitoring and evaluating EDM policies success

Efforts to improve energy efficiency and reduce demand have been described as the most effective, rapid, cost-efficient, and secure approach to combat climate change (Sorrell, 2015). More recently, energy efficient and demand management are also identified as needed for supporting the flexibility required by the electricity grid management in a context of increasing intermittent renewable energy in the energy mix. Yet, previous attempts to diminish energy demand have not consistently proven effective, gathering varied levels of attention across European countries, and influenced temporarily by external shocks. Suppliers often prioritize load management over reducing consumption levels and accordingly develop strategies and allocate investments (Pyrko & Darby, 2011). The outcomes of these strategies become evident when analysing EU investment data to decarbonise the economy, where overall investments in energy production, even in renewable sources, significantly exceed investments allocated to energy consumption (European Commission, 2023; I4CE, 2024; Institut Rousseau, 2024; Wiese et al., 2024). Echoing this evidence, Royston et al. (2018) highlight that many policymakers and organizations, both at national and local levels, have not reevaluated their institutional objectives or procedures in response to the climate change challenge. Instead, they've mainly focused on setting ambitious carbon reduction goals without changing other priorities, like plans for growth (Royston et al., 2018).

Given the challenges in effectively utilizing price signals to drive change, a combination of policies is necessary to channel funds into investments that facilitate long-term reductions in energy demand. Consequently, there is a pressing need for researchers and policymakers to enhance their understanding of governing energy demand, both individually and collaboratively, in order to foster sustainable shifts in energy consumption patterns (Royston et al., 2018).

## 3.1 The need of good monitoring and evaluation for the implementation of energy demand management policies

### 3.1.1 About monitoring and evaluation

Effective monitoring and evaluation are essential for measuring the success of EDM policies. A global systematic review identified lack of monitoring and technical issues as the most pressing failure factors for the success of these policies across different countries (Warren, 2015).

Policy evaluation should provide a fair comparison between **actual outcomes with expected ones**. It goes beyond just measuring results, but also tries to understand why those results happened and how they are connected to the program itself. Evaluations use various methods to gather evidence and ultimately inform decisions about whether a program should continue, be changed, or ended altogether (Renders et al., 2020). Evaluation findings provide a solid scientific basis for policymaking, informing the development of new policies and enhancing existing ones. Evaluations can also play a crucial role in efficient resource allocation, showcasing the utilization of funds, thereby promoting accountability, and potentially ensuring the continuation of policies.

Policy evaluation should entail monitoring policy implementation from its inception through to the post-policy evaluation phase, with ongoing assessment during the implementation process (Nazarova & Barmina, 2021):

- Tracking implementation: Monitoring how the policy is being rolled out. This includes identifying any challenges or deviations from the original plan.

- () Active evaluation throughout: Continuously assessing the policy's impact during implementation. This allows for adjustments and course corrections if needed.
- () Post-policy evaluation: Assessing the long-term effects of the policy after its full implementation.

Evaluating energy saving policies typically involves two approaches: **ex-ante** and **ex-post**. Ex-ante appraisals forecast a policy's potential impact beforehand, relying on engineering models and projected savings. While they offer faster and more cost-effective evaluations, their reliability may be lower. In contrast, ex-post evaluations assess the actual impact of a policy post-implementation, offering more dependable data but demanding greater resources for monitoring.

### 3.1.2 What aspects should monitor, and evaluation plans cover?

The evaluation criteria outlined by the Better Regulation (EC, 2017)[6] emphasizes the importance of considering various criteria, which can be grouped into two main categories. The primary criteria ensure that policies achieve their intended outcomes cost-effectively while aligning with broader energy strategies and addressing current challenges. The secondary criteria assess factors like fairness, stakeholder involvement, long-term sustainability, and public acceptance, all crucial for the policy's overall success and longevity (see Table 4). According to the Better Regulation guidelines, assessing policies against these specific criteria is an initial step to determine their true value, providing a basis for understanding their real-world impact. More detailed information and a wider range of considerations regarding this evaluation process can also be found in Renders et al., 2020.

*Table 4: List of evaluation criteria to be considered when evaluating policy schemes according to the Better Regulation (EC, 2017).*

| Criteria | Description & Indicative question |
|---|---|
| **Primary** | |
| **Effectiveness** | Defined as the progress towards intervention objectives and linking changes to the intervention:<br>**"Did the policy achieve its intended goals of reducing energy demand?"** |
| **Efficiency** | Examining costs and benefits, assessing proportionality, and identifying opportunities for streamlining: **"Were the goals achieved in a cost-effective manner?"** |
| **Coherence** | Assesses the coherence of the policy with other actions: **"Does the policy align with other relevant policies and initiatives?"** |
| **Relevance** | Evaluates the alignment of intervention objectives with current needs and technological advancements: **"Was the policy designed to address the specific needs and challenges related to energy demand reduction?"** |

[6]) https://commission.europa.eu/law/law-making-process/planning-and-proposing-law/better-regulation/better-regulation-guidelines-and-toolbox/better-regulation-toolbox_en

| Criteria | Description & Indicative question |
|---|---|
| **Secondary** | |
| **Equity** | Ensures no one group shoulders a disproportionate burden of the policy: **"Does the policy fairly distribute the costs and benefits across different groups of people?"** |
| **Utility** | Informs future efforts to reduce energy demand: **"Does the policy provide valuable information or insights for future policy development?"** |
| **Complementarity** | Strengthens the overall effect of energy-saving efforts: **"Does the policy work well alongside other existing policies to maximize impact?"** |
| **Coordination** | Improves buy-in and ensures the policy addresses practical concerns: **"Were stakeholders involved effectively in the policy design and implementation?"** |
| **Sustainability** | Ensures long-term impact on energy consumption: **"Can the policy's benefits be sustained over the long term?"** |
| **Acceptability** | Increases the likelihood of successful implementation and long-term support: **"Is the policy socially and politically acceptable to the public and relevant stakeholders?** |

### 3.1.3 What are the main challenges to bear in mind for energy demand management?

When it comes to rigorously assessing the primary goal of energy demand reduction policies, a series of additional steps are defined as crucial parts of the monitoring and evaluation practice. These steps aim to ensure that these policies achieve their primary goal: achieving real, targeted savings (Warren, 2015) while accounting for specificities related to their implementation. These steps include:

1. Verification: Regular verification ensures the accuracy of the data collected.
2. Energy consumption baseline: This establishes a benchmark for comparison. It involves measuring energy consumption before the policy is implemented.
3. Gross savings adjustments: Measured energy savings might not solely be due to the policy - so adjustments need to be made to account for external factors like weather changes or economic trends.
4. Attribution of energy savings: Isolating the true impact of the policy can be challenging. This step involves attributing the observed energy savings to the policy itself, separating them from the influence of other factors.
5. Unintended effects: Importance to consider the potential unforeseen consequences of policies or actions.

Each of these steps has associated subfactors or considerations that necessitate further consideration to avoid potential pitfalls. The following table lists and describes these factors, as outlined in Warren (2015), along with others identified in the literature. See Table 5 below.

*Table 5: Important considerations in evaluating energy demand reduction policies. Source:Adapted from Warren et al., 2015.*

| Step | Considerations | Description |
|---|---|---|
| Verification | Quality standards | Implementing robust data collection protocols to ensure accurate and reliable information on energy consumption |
| Verification | Double counting | Preventing double-counting of energy savings with normalization techniques and clear measurement boundaries |
| Energy consumption baseline | Building fabric Characteristics | Considering building characteristics (e.g., insulation levels) that can influence energy use |
| Energy consumption baseline | Use of new equipment | Considering how the installation of new energy-saving equipment (solar panels, appliances) affects energy use |
| Energy consumption baseline | Early equipment replacement | Evaluating how the policy encourages replacing older, less efficient equipment with newer, more efficient models |
| Energy consumption baseline | Calculation method used | Setting a benchmark for comparison by measuring energy use before the policy takes effect |
| Gross savings adjustments | Technical interaction between measures | Understanding how various policy tools work together or against each other to impact energy consumption |
| Gross savings adjustments | Measure lifetime | Finding out how long the energy-saving measures from a policy will last is crucial for understanding its long-term impact on energy use |
| Gross savings adjustments | Normalisation factors | Adjusting raw data on energy savings achieved by a policy to accommodate various factors that could impact the measured results |
| Gross savings adjustments | Rebound effects | Energy savings may be offset by changes in behaviour, where saved energy is used for additional energy-consuming activities |
| Gross savings adjustments | Jevon’s paradox | A subtype of rebound effect, showing how energy efficiency improvements can paradoxically increase overall energy consumption |
| Gross savings adjustments | Conversion factors | Incorporating conversion factors to standardize energy savings reporting across sectors ensures consistency in policy evaluations |
| Gross savings adjustments | Fuel switching | Considering that a policy aiming to reduce overall energy consumption can inadvertently cause a shift in the types of fuels use |
| Gross savings adjustments | Locks-in effect | Existing infrastructure, technologies, or behaviours create challenges for adopting new, more energy-efficient alternatives |
| Attribution of energy savings | Free riders | To account for individuals or entities benefiting from the policy's outcomes without directly contributing to them |
| Attribution of energy savings | Additionality | Disentangling policy impacts, particularly in relation to direct energy savings or emissions reductions of the targeted policy |

| | | |
|---|---|---|
| Attribution of energy savings | Synergies | As opposed to additionality, positive interactions between two or more policies can multiply their intended effects (1+1=3) |
| Attribution of energy savings | Market transformations | Ensuring sustainable and lasting markets shift, where energy-saving choices become the norm rather than a niche option |
| Unintended effects | Trade-off | Pursuing one policy or action might lead to negative consequences for another desirable outcome, resulting in a "win-lose" scenario |
| Unintended effects | Burden shifting | Considering that a policy aimed at addressing an energy-related issue in one area unintentionally transfers the burden to another area |

## 3.2 Good examples of policy monitoring/evaluation of EDM policies

### 3.2.1 Warmer homes Scotland

Warmer Homes Scotland is a Scottish Government-funded scheme that provides energy efficiency improvements to eligible low-income households, with a focus on alleviating fuel poverty and reducing carbon emissions. The program conducts an annual ex-post evaluation to assess its reach, measure its impacts, and identify areas for improvement. The yearly assessment examines the number of households assisted, the most commonly implemented measures, energy savings, environmental benefits, customer satisfaction, and social and health outcomes. The program's common measures include installing insulation, upgrading heating systems, and fitting energy-efficient windows and doors. It also quantifies the reduction in fuel bills and estimates the decrease in carbon emissions. Furthermore, customer feedback is collected to evaluate satisfaction levels and perceived improvements in comfort and health pre-post intervention. This assessment is periodically reviewed, with the yearly report pinpointing areas for improvement, such as reducing waiting times or increasing the number of households benefiting, to enhance implementation in the subsequent year.

***Why is it a good example?***

- It considers baselines of consumption and wellbeing to assess improvements over the middle-term.
- The assessment uses various KPIs to evaluate the real impact, including disregarded effects such as social return on investment (SRoI).
- It incorporates future elements based on evidence to reshape and strengthen the policy's impact.

### 3.2.2 Socio-economic and public health impact of the national integrated energy and climate plan 2021-2030 of Spain

The assessment analyses the socioeconomic and public health impact ex-ante of the National Integrated Energy and Climate Plan (PNIEC) of Spain for the years 2021-2030. The analysis is done using an existing multisectoral and multihousehold economic model called DENIO, which integrates massive information from 78 main productive sectors and 22,000 households. The report provides accurate estimates of the economic impact the plan would have on the national economy, with an additional GDP generation of 16,567-25,750 M€ per year (1.8% of GDP in 2030). This is related to significant investments in local renewable energy generation that allow reducing energy imports, increasing energy independence. Energy savings are also accurately included and argued to represent an important aspect for GDP growth, as they allow liberating economic resources that could be reinvested. These energy saving objectives across different sectors are estimated at around 50,000-55,000 ktoe accumulated during the period, which implies a 44% efficiency improvement in 2030. The report also estimates that the impacts of the measures should gain effect over the years as fossil fuel consumption and imports are reduced. Importantly, the report analyses distributive effects that favour low- and middle-income groups and vulnerable group and even estimates effects on public health from a reduction in pollution.

***Why is it a good example?***

- It relies on an existing multisectoral economic model for its analysis, utilizing historical proxies and predefined consumption baselines.
- It includes macroeconomic, social, and public health impacts, going beyond other monitoring tools that focused only on the energy sector or partial costs/benefits.
- The year-by-year analysis quantifies dynamic benefits, and sensitivity analyses on key variables like fossil fuel prices highlight the importance of accounting for uncertainty.

### 3.2.3 Subsidy scheme for energy savings in social housing of Amsterdam

The municipality of Amsterdam implemented a subsidy scheme to incentivize energy efficiency improvements in the social housing sector. The scheme provided subsidies to housing associations to implement energy-saving measures in their housing stock. Part of the eligible criteria was the implementation of a monitoring and evaluation framework, requiring housing associations to report on the pre- and post-retrofit energy consumption of the buildings. An independent third-party organization verified the reported energy savings. Over the 2008-2013 period, the scheme supported upgrades in over 30,000 social housing units, resulting in 30-40% reductions in energy use per dwelling and total annual energy savings of around 100 GWh. The rigorous monitoring and verification system was key to ensuring the program's impacts were accurately tracked and validated, contributing to its success in driving persistent energy demand reductions in the social housing sector.

***Why is it a good example?***

- The program included a detailed monitoring involving housing associations and an independent verifier.
- Real data was used to calculate the total energy and cost savings, as well as the associated CO2 emissions reductions, providing rigorous metrics.

## 3.3 The need to enhance energy demand management policy effectiveness.

While effective EDM policies clearly require continuous monitoring and evaluation to stay relevant and impactful, they are often complex and involve a multitude of factors that contribute to their success. These factors might include policy design, financial and technological resources, stakeholder engagement, public perception, and mechanisms for adaptation. The interplay of these factors can vary significantly across different contexts, creating a complex web of interactions.

For example, advancements in smart technologies and renewable energy integration present significant opportunities for optimizing energy use and achieving climate targets. However, addressing behavioural challenges and ensuring equity in policy design are equally critical for securing broad consumer adoption and ensuring the long-term success of EDM initiatives (Rovers, Kooger, & Tigchelaar, 2021). As discussed, policymakers need to create a supportive environment for investing in energy efficiency and enhance consumer awareness to optimise the use of energy. While it seems that EDM policies are overall positively influencing energy consumption in the EU (Labandeira et al., 2020; World Economic Forum, 2021), many policies either fail to deliver results or produce counterproductive effects (Sokołowski & Heffron, 2022). This complexity is understandable given the intricate system at play.

Modern data analytics and artificial intelligence provide powerful new tools to understand and manage the complexity of policy systems, allowing for deeper insights than traditional methods can offer. Systemic modelling techniques, such as Fuzzy Cognitive Mapping (FCM), are becoming increasingly used at this regard. FCM allows for the visualization and analysis of complex relationships within policy frameworks by mapping out interconnected factors and their influence on one another. By incorporating both qualitative and quantitative data, FCM can simulate how changes in one part of a system may impact other areas, helping to capture the non-linear, dynamic nature of real-world policies. Hence, these advanced tools allow policymakers to identify key leverage points within systems, test various policy scenarios, and predict potential outcomes under different conditions. This not only empowers informed decision-making but also facilitates the testing of policy interventions tailored to the specific needs, preferences, and constraints of different regions or demographics.

## 3.4 What are the factors making EDR policies effective? System mapping analysis of energy demand policy effectiveness

In the following paragraphs, the focus is on a specific aspect of EDM policies: Energy Demand Reduction (EDR) policies. The aim is to explore the system dynamics that contribute to the success of these policies by utilizing **expert knowledge**. To achieve this, system mapping is used, a methodology that enables to examine the complex interactions among various factors influencing policy outcomes. The objective is to capture the intricacies of the system and develop an expert model that allows to test different scenarios. This approach will help to address the critical question: **What makes EDR policies effective?**

### 3.4.1 Why system mapping?

System mapping analysis provides a robust framework for assessing the effectiveness of EDM policies. Unlike traditional methods, system mapping goes beyond identifying individual relationships between potential drivers or barriers and the target factor (objective). It explores how these factors interact and influence one another within the broader system. This approach enables the identification of key factors shaping policy outcomes and uncovers potential unintended consequences or feedback loops that might otherwise go unnoticed. An additional advantage lies in its ability to facilitate scenario testing. By simulating different scenarios, the interplay among actors presented in the system can be explored. This approach allows to evaluate how variations in some of the system factors (e.g., consumer behaviour, technological advancements) impact the objective or target factor (e.g., success of EDR policies). These simulations provide valuable insights into the potential outcomes of different policy interventions, ultimately informing the most effective strategies.

### 3.4.2 Fuzzy Cognitive Maps (FCM)

*Fuzzy Cognitive Maps (FCMs) were introduced by Kosko as an extension to traditional cognitive maps, offering a method for modelling and analysing complex systems (Kosko, 1986; See*

Figure 9). In contrast to other methods that rely on crisp binary relationships (on/off, true/false), FCMs incorporate fuzziness, acknowledging the uncertainties and gradual changes that often exist in real-world systems. This fuzziness is achieved by using information granules within the nodes of the FCM (Mkhitaryan et al., 2022), connected by weighted direct edges marking relationships between nodes. Thus, FCMs are composed of:

- **Nodes**: that represent the key components or factors of the system (concepts, events, etc.) and harness information granules.
- **Weighted edges:** that depict the causal relationships between nodes. The weights on the edges signify the strength and direction (positive or negative) of the influence that one component has on another.

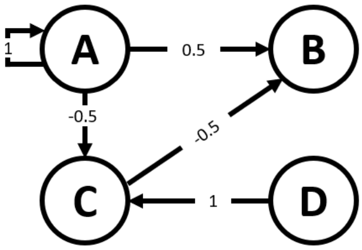



*Figure 9: A basic fuzzy cognitive map (FCM), featuring weighted edge relationships (-1, 1) between node elements A, B, C, and D.*

**Source**: Gray et al. 2015.

The combination of information granules and weighted edges allows FCMs to be a valuable tool to capture expert knowledge in a given area. Experts can use FCMs to represent their understanding of the system, including the uncertainties and gradual changes that are often difficult to capture with other methods. The dynamics of the system are examined by simulating its behaviour over discrete simulation steps. Hereto, is this simulation process each node's state is repeatedly updated based on the effects of the nodes it is connected to and the strength of those connections (Mkhitaryan et al., 2022).

### 3.4.3 Exploring energy demand policy effectiveness through FCM analysis

In the analysis, fuzzy cognitive mapping methodology was used to map and relate the factors influencing energy demand policy effectiveness.

#### 3.4.3.1 Methodology

In a first step, a review of literature on the effectiveness of EDR policies was performed. Two main documents were selected for this purpose:

- Warren, P. (2015). Demand-side management policy: mechanisms for success and failure (Doctoral dissertation, UCL (University College London)).
- Renders, N., Meynaerts, E., Seizov, P., Medarska, T., Lonsdale, J., & Kisielewicz, J., (2018). Assessment of the implementation status and effectiveness of Article 17 of the Energy Efficiency Directive (Publications Office of the European Union)

Based on these, a total of 19 factors were preselected (see Table 6). The identified factors have the potential to influence the successful implementation of EDR policies, either as drivers or barriers. Each factor was carefully labelled to indicate its effect directionality. For example, the impact of public opinion was framed positively as "Good alignment with public opinion values." It's important to note that these designations were somewhat arbitrary, as the factors could have been defined in the opposite direction, such as "Bad alignment with public opinion values." In addition, to prevent misunderstandings, each factor was described briefly in a paragraph (see Table 6).

*Table 6: List of factors influencing the effectiveness of energy demand reduction policies.*

| Factor name | Description |
|---|---|
| **Favourable regulatory frameworks** | Presence of supportive policies, laws, and regulations that facilitate the adoption and implementation of energy demand reduction initiatives. These frameworks create an environment conducive to promoting energy efficiency, reducing consumption, and encouraging sustainable practices in various sectors such as industry, transportation, and residential buildings. |
| **Existence of split-incentive issues** | Situations where the party responsible for making decisions about energy efficiency improvements or investments (e.g., landlords, property owners) is different from the party who benefits from the resulting energy savings (e.g., tenants, occupants). This misalignment of incentives can create barriers to implementing energy efficiency measures, as the party bearing the upfront costs may not directly reap the financial benefits of reduced energy consumption. |
| **Good alignment with public opinion values** | Unfavourable attitudes, beliefs, or opinions held by members of the public regarding a particular policy, program, or initiative aimed at energy demand reduction. This perception can arise due to various factors, such as misconceptions about the effectiveness or impacts of the policy, concerns about its potential drawbacks or inconveniences, distrust in the institutions or actors implementing the policy, or disagreement with the underlying principles or objectives of the initiative |
| **Existence of other overlapping or opposed policies** | Situations where different policies, regulations, or strategies within a particular domain overlap with each other or are in direct conflict, potentially hindering effective implementation or causing confusion among stakeholders. |
| **Inappropriate group targeting** | Policies, programs, or interventions are not effectively directed towards the intended beneficiaries or objectives. This can occur when the criteria used to identify the target population are inaccurate, insufficient, or misaligned with the desired outcomes. |
| **Lack of needed technology or innovation levels** | It refers to the existing technological solutions and innovative approaches that can be leveraged to reduce energy consumption, enhance energy efficiency, and promote sustainable energy practices. This includes a wide range of technologies such as energy-efficient appliances, renewable energy systems, smart grid technologies, energy management systems, or advanced analytics tools. |
| **Stable long-term policy with a clear mandate for the implementation entity** | Consistent implementation and maintenance of policies over time, often across different political administrations or changes in leadership. It implies the absence of significant disruptions or reversals in policy direction, ensuring stability and predictability in governance. |
| **Good transparency and trustworthiness of the policy** | Extent to which a policy is open, clear, and accountable to stakeholders, fostering confidence and credibility among the public. |

| | |
|---|---|
| **Governance structure and leadership clarity** | Organizational frameworks and leadership roles established to guide the development, implementation, and enforcement of these policies. It involves defining the responsibilities of government agencies, regulatory bodies, energy utilities, and other stakeholders involved in shaping and executing energy demand reduction initiatives. |
| **Continuous financial support available** | Presence of financial resources that are sustained over an extended period, typically beyond short-term budget cycles. It signifies stable and predictable funding streams that enable ongoing support for initiatives, programs, or projects without the risk of sudden disruptions or budget constraints. |
| **Flexibility to adopt changes or include modifications** | Capacity of a policy framework to adapt and incorporate modifications in response to evolving circumstances, feedback, or new information. It indicates the ability to adjust strategies, approaches, or regulations as needed to address emerging challenges, seize opportunities, or better align with shifting priorities or objectives. |
| **Adequate information and expertise** | It refers to having the necessary knowledge and skills available to effectively implement and manage a project or policy. This includes access to relevant data, understanding of the subject matter, and proficiency in the required techniques or methodologies. |
| **Support from industry and stakeholders** | Level of endorsement, cooperation, and active involvement of various industries, businesses, organizations, and stakeholders in the implementation and advancement of the energy demand reduction policy. This support can manifest in different ways, including advocacy, collaboration, investment, resource allocation, and participation in policy development and implementation processes. |
| **Poor consumer engagement** | Situation where consumers are not actively involved or motivated to participate in initiatives, programs, or policies related to energy demand reduction. This lack of engagement can occur for various reasons, such as limited awareness or understanding of the benefits, lack of incentives or perceived value, distrust in the effectiveness of the measures, or barriers preventing meaningful participation. |
| **Ease of implementation of the policy** | How straightforward and feasible it is to put a policy or strategy into action. It considers factors such as practicality, resource availability, administrative capacity, and the absence of significant barriers or obstacles. Essentially, it assesses the degree of difficulty or simplicity involved in executing a particular plan or initiative. |
| **Lack of monitoring** | Absence or inadequacy of systems and processes designed to observe, track, and evaluate the implementation and outcomes of policies or initiatives. It suggests a failure to effectively measure progress, identify areas for improvement, and ensure accountability in achieving desired objectives. |
| **Existence of negative behavioural effects** | The presence of anticipated effects derived from the behaviour of citizens such as the rebound effect or the free riders. Rebound effects occur when saved energy is used more elsewhere, and free riders exploit energy savings without contributing, potentially negating overall benefits. |

| | |
|---|---|
| **Unequal impact on vulnerable groups** | Unintentional policy effects that exacerbate existing socioeconomic disparities by disproportionately burdening low-income groups or hindering their ability to benefit compared to higher-income groups. |
| **Proved cost-effectiveness** | Demonstration or evidence that a particular policy, program, or intervention aimed at energy demand reduction delivers tangible benefits in relation to the resources invested. This evidence typically involves rigorous analysis showing that the monetary or resource savings achieved through the implementation of the policy outweigh the costs incurred in its development, implementation, and maintenance. |

#### 3.4.3.2 Data acquisition

A total of 13 experts were interviewed coming from 11 different energy agencies across Europe including Oeko and DENA (Germany), Energy Saving Trust (UK), RVO (Netherlands), ADENE (Portugal), AEA (Austria), SIEA (Slovakia), Energimyndigheten (Sweden), Informa Echo (Slovenia), DEA (Denmark), CENER (Spain) and SEAI (Ireland). Before the interview, the experts were provided with the list of factors and their definitions, asking them to review these carefully. This was to ensure their familiarity with the factors in beforehand. During the online interview, which lasted approximately 1 hour, experts were initially introduced to the research question: "What are the key factors contributing to the success of energy demand reduction policies in your country?" Two definitions were provided to clarify the concepts of "success" and "energy demand reduction policies". These definitions are in line with the framework outlined by European Energy Research Alliance (2023) in "*Energy Demand Reduction as Part of the Clean Energy Transition in Europe: Research and Policy Strategies*".

- *Success* in energy demand reduction policies was referred as: "*Achieving targeted reductions in energy consumption, enhancing energy efficiency, and meeting set objectives. It involves reducing energy usage, promoting sustainable practices, gaining public support, and delivering positive environmental, social, and economic outcomes*".
- Energy demand reduction policies were on its turn defined as: "*Policies that encompass various strategies aimed at decreasing energy consumption. These strategies include traditional concepts like energy efficiency as well as more nuanced approaches such as energy sufficiency. Additionally, they involve promoting "behavioural change," which influences decision-making patterns to facilitate the successful adoption of energy efficiency and sufficiency measures*".

Following this, participants were provided with a brief explanation of how FCMs work and what was expected from them during the interview. Additionally, instructions were given along with a visual scheme illustrating a simple example of an FCM:

– *"Fuzzy cognitive maps (FCM) are a tool that helps us organize and understand our thoughts about a particular topic. It's like creating a mental picture or model of how we perceive the issue. FCM focuses on how different factors or variables interact with each other. When using FCM, we consider 3 important aspects:*

1. *Identification of the factors impacting the system*
2. *The direction of the relationship between variables (whether it's positive or negative)*
3. *The strength of that relationship (Very High, High, Medium, Low, Very Low – linguistic ratings)"*

The selection of linguistic ratings was chosen to help participants articulate the magnitude of the relationships (Mkhitaryan et al., 2022). During the interview, participants were neutrally guided and challenged regarding the direction and strength of the relationships between the factors to avoid influencing their thoughts. Additionally, participants were encouraged to introduce new factors or elements they deemed important beyond the 19 preselected ones. Once the exercise was finished, they were provided with the map they created and were invited to provide additional inputs or modify the existent ones.

#### 3.4.3.3 Scenario analysis

A combined approach is applied to generate scenario analysis. All the interventions were based on changes in baseline values for the existing factors within the fuzzy cognitive model generated (single-shot intervention; see Mkhitaryan et al., 2021). This approach is intended to create and test distinct scenarios, allowing for a better understanding of their impact on EDR.

Based on current policy and market trends, **three + one intervention scenarios** were defined. The first three were predefined, and the fourth would be built upon the results from the centrality analysis that resulted from the graph analysis done to identify the most influential nodes and their connections within the network. The list of the scenarios evaluated is the following: (for more information see "***Scenarios definition***" in the annexes).

- **Scenario 1** examines how **increased support from market actors**, driven by R&D investments, impacts energy demand reduction efforts. It assumes strong participation from industry and stakeholders.
- **Scenario 2** looks at how **worsening** conditions at the policy level affect **monitoring and evaluation**. It simulates negative impacts on policy control and implementation.
- **Scenario 3** explores the effects of **providing targeted information** to users to promote energy-saving behaviours (See box 3 and Section 3 of this report).
- **Scenario 4** uses betweenness centrality analysis to identify key factors that accelerate the spread of the target factor, increasing the weight of these central factors by 25%.

**Box 3 Human nature's barrier to demand reduction policies.**

When considering the lack of commitment given to demand reduction policies, one cannot overlook the influence of human rationality. In recent years, numerous experts have shed light on the imperfect nature of human decision-making processes. Unlike the traditional economic theory of rationality, which posits that individuals make optimal decisions with complete information and unlimited cognitive abilities, the concept of bounded rationality proposes a different perspective. Bounded rationality acknowledges the cognitive limitations that shape decision-making, where individuals must navigate constraints such as limited information and time. This concept, rooted in psychology and behavioural economics, underscores the inherent challenges individuals face when making decisions.

As demand reduction policies often rely on individual consumers, their actions can significantly impact the effectiveness of these policies in achieving their goals. A prominent illustration of this dynamic is the well-documented rebound effects (Greening et al., 2000). Studies have shown that bounded rationality tends to amplify rebound effects by encouraging higher energy consumption through increased usage intensity and reinvestment in energy-intensive products (Exadaktylos & Van Den Bergh, 2021). Consequently, anticipated savings are compromised, and investment efforts in demand reduction discouraged. Additional challenges associated with bounded rationality and the pursuit of demand reduction through maximizing expected benefits stem from cognitive biases such as status quo, loss aversion, or present bias. For example, existing defaults and habits, as well as loss aversion, could impede the adoption of energy-efficient products by reinforcing the status quo, thereby weakening the link between intentions and behaviour (Bensouda & Benali, 2022; Bertoldi, 2022; Exadaktylos & Van Den Bergh, 2021). Interestingly, some of these challenges can also be part of the solution. Behavioural interventions, particularly those leveraging technology to offer accurate information, can be effective in promoting the adoption and efficient use of energy-saving technologies. For example, smart meters can help counteract negative effects of inattention, habits, and inertia on energy consumption (Exadaktylos & Van Den Bergh, 2021). Social norms can also be a powerful tool. Promoting energy-saving behaviours and the adoption of efficient technologies through social influence can be very effective.

## 3.5 Results from the FCM analysis

### 3.5.1 Matrix of relationship strengths

The experts from the various European countries identified an average of 33 links between the factors, with a 95% confidence interval ranging from 26.52 to 40.39. The distribution of the linguistic terms used was asymmetrically distributed with more positive relationships identified (see Figure S1).

The causal relationships strengths across all countries were quantified by converting linguistic terms into crisp values, which were then aggregated globally (for more information check "**Error!**

**Reference source not found.**” in Annex I). The results of this aggregation provided a general matrix illustrating the causal relationships between the distinct factors (see Figure 10).

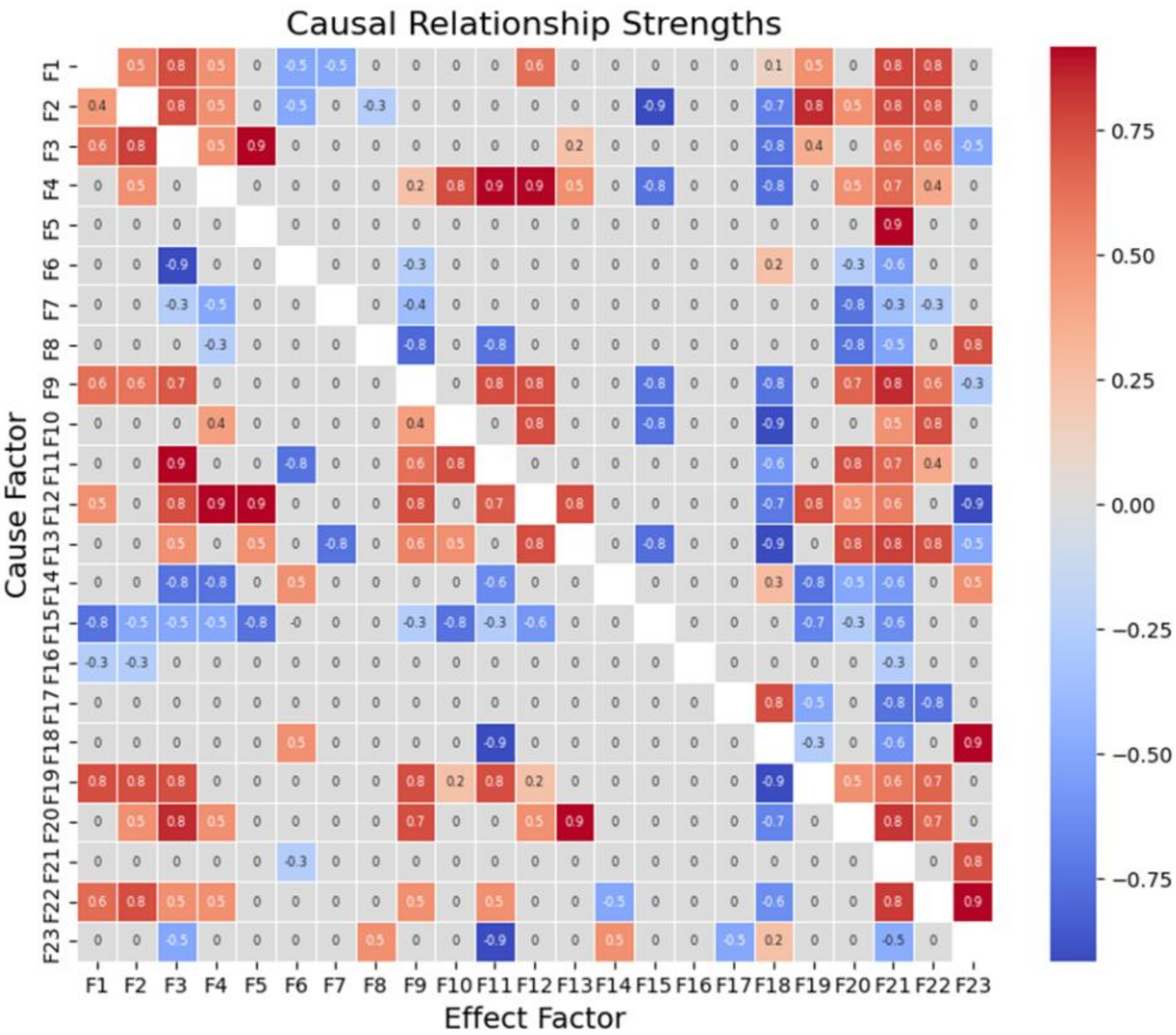



*Figure 10: Matrix depicting the causal relationships among the different factors and the target (F21). Values are calculated by applying fuzzy logic to the linguistic terms used by experts to assess the relationships among the factors involved in the study, and then aggregated to identify a unique causal strength.*

The factors are denoted as F"s" in the graph, the target factor under study (F21) is highlighted in the box below. In addition to the 19 factors identified in literature, experts introduced three additional factors, coloured in the list below:

F1: Adequate information and expertise
F2: Available technology or innovation levels
F3: Continuous financial support available
F4: Ease of implementation
F5: Existence of local expertise network favouring implementation
F6: Existence of negative behavioural effects
F7: Existence of other overlapping or opposed policies
F8: Existence of split-incentive issues
F9: Favourable regulatory frameworks
F10: Flexibility to adopt changes or include modifications
F11: Good alignment with public opinion values
F12: Good transparency and trustworthiness
F13: Governance structure and leadership clarity
F14: Inappropriate group targeting
F15: Lack of monitoring
F16: Lack of skilled workforce
F17: Low energy prices
F18: Poor consumer engagement
F19: Proven cost-effectiveness
F20: Stable long-term policy with a clear mandate
**F21: Successful energy demand reduction policy in your country**
F22: Support from industry and stakeholders
F23: Unequal impact on vulnerable groups

### 3.5.2 Understanding expert agreement through entropy analysis

To assess the level of agreement among experts regarding the importance of factors influencing a policy's success, entropy values were computed across experts. Entropy is useful to measure uncertainty or randomness. Higher entropy values indicate greater disagreement among the experts. The entropy for each factor (F1-F23) was calculated based on expert ratings. Analysis of these entropy values revealed two areas of factors:

**Areas of strong consensus (Low entropy)**

**Factors with relatively low entropy values** suggest a **higher level of agreement** among the experts regarding their importance for policy success. These factors might be seen as key for a successful policy and included:

1. Available technology or innovation levels: Experts tend to agree on the importance of technology innovation in implementing and achieving EDR policies.
2. Ease of implementation: Simplicity in implementation appears to be important across the majority of countries.
3. Existence of other overlapping or opposed policies: Experts generally agree that overlapping or opposed policies in their countries do not have a significant overall impact.

4. Favourable regulatory frameworks: These are required across all countries for the successful implementation of EDR policies.
5. Good transparency and trustworthiness: Experts tend to agree that this factor generates confidence in EDR policies.
6. Governance structure and leadership clarity: Similar to transparency, governance structure is also seen as relevant.

**Areas of potential disagreement (High entropy)**

Factors with high entropy values indicate greater disagreement among the experts. This highlights areas where further discussion or clarification might be necessary. These included:

1. Continuous financial support available: Experts might disagree on the optimal level or duration of financial support needed for policy success.
2. Existence of split-incentive issues: This factor might have different impacts across the interviewed countries.
3. Good alignment with public opinion values: Disagreement could arise regarding how much weight to give to public opinion when defining a policy.
4. Lack of monitoring: Experts appear to differ on the appropriate level and intensity of monitoring needed to track policy progress.
5. Poor consumer engagement: There might be disagreement about the most effective strategies for engaging consumers or their specific importance in promoting EDR policies.
6. Proven cost-effectiveness: Experts might have varying opinions on the acceptable level of costs for achieving the desired policy outcomes.
7. Unequal impact on vulnerable groups: Disagreement could exist regarding the best ways to mitigate the policy's potential negative impact on vulnerable populations, which appears to vary significantly across countries.

### 3.5.3 System centrality

Centrality measures enable us to identify the most important nodes of factors within a system the influential nodes, i.e., those that predominantly disseminate information to other nodes, and those that play a crucial role in explaining the system's behaviour.

**Degree of centrality**

Degree of centrality assumes that important nodes have many connections. According to the results observed, the factors listed in Table 7 have a high degree of centrality in promoting successful energy demand reduction policies.

*Table 7: Degree of centrality and direct weighted effect on the node factors according to their centrality in the success of Energy Demand Reduction Policies.*

| Factor | Degree centrality [0, 1] [7] | Closeness centrality [0, 1] | Betweenness centrality [0, 1][8] | Direct weighted effect on EDR success |
|---|---|---|---|---|
| Continuous financial support available | 0.82 | 0.85 | 0.04 | 0.62 |
| Favourable regulatory frameworks | 0.82 | 0.85 | 0.031 | 0.85 |
| Poor consumer engagement | 0.78 | 0.81 | 0.031 | -0.61 |
| Ease of implementation | 0.73 | 0.79 | 0.023 | 0.65 |
| Stable long-term policy with a clear mandate | 0.73 | 0.79 | 0.022 | 0.82 |
| Support from industry and stakeholders | 0.73 | 0.79 | 0.03 | 0.81 |
| Available technology and information levels | 0.6 | 0.71 | 0.024 | 0.75 |
| Adequate information and expertise | 0.6 | 0.71 | 0.024 | 0.76 |

Notes: Light blue highlights the factors with the highest centralities. Last column displays direct weighted effects on the target factor Energy Demand Reduction policies success.

The specific weight of these factors is also significant when it comes to the direct effect on the success of EDR policies (see Table 7 and Table 11) It is important to note that the weight of these factors can be negative, depending on how they are framed, as in the case of poor consumer engagement which appears to show a detrimental impact on the success of EDR policies.

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[7]) See "System centrality" in the annex for more information.

[8]) Please note that there is ongoing discussion about the appropriateness of using Betweenness Centrality, as it may lead to the misestimation of the impact of negative nodes (see Mkhitaryan et al., 2020).

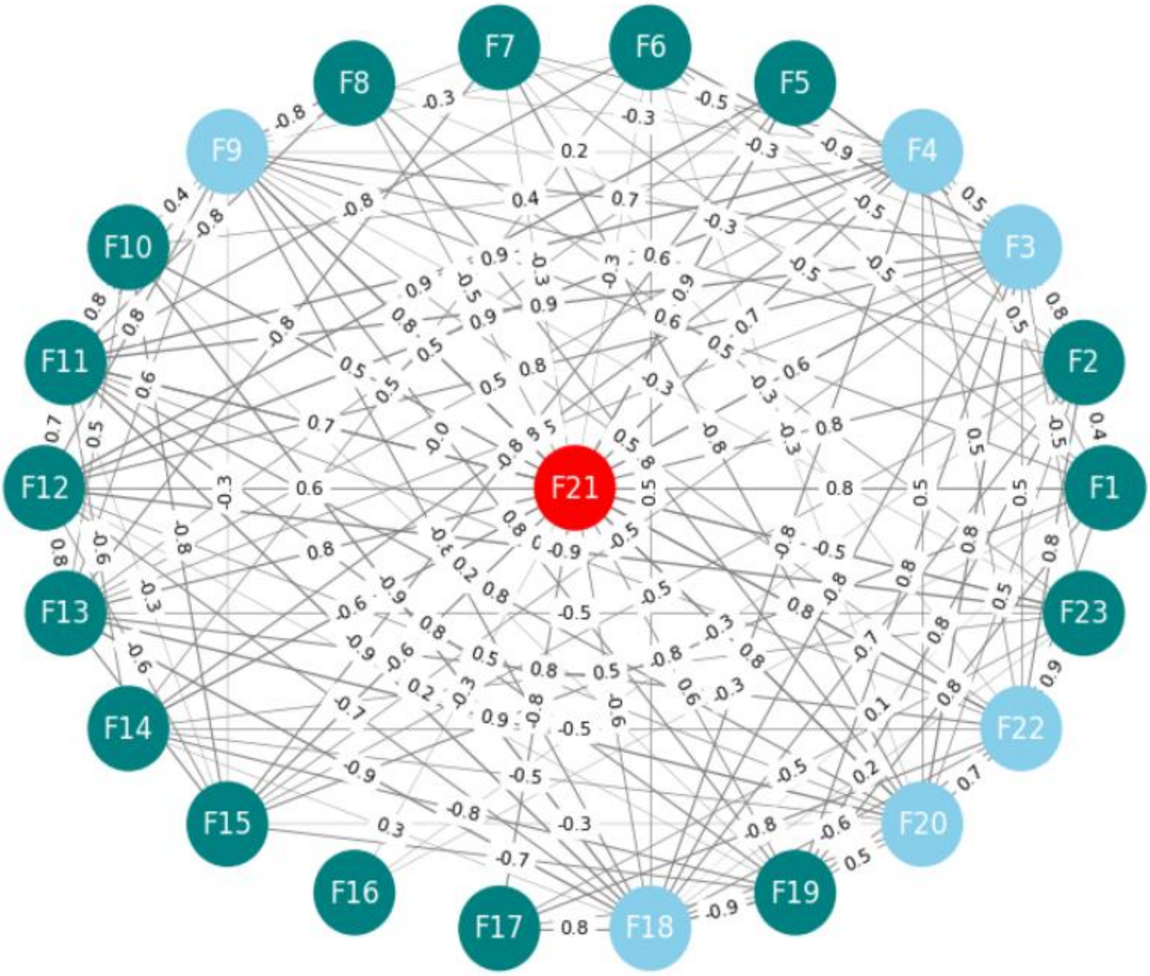


*Figure 11: Graph network depicting the set of factors investigated and their interconnections, along with their relationships to the target factor (F21: Successful implementation of energy demand reduction). Factors highlighted in light blue denote those identified as centrally influential within the system, as determined by degree and closeness centrality.*

Closeness centrality

Closeness centrality considers how quickly information can be spread from a factor to all others. A factor with high closeness centrality is, on average, closer to all other factors, making it a strong central point for spreading information. The results show that the top nodes for information dissemination are the same six most central nodes identified by another measure (seeTable 7).

Betweenness centrality

Betweenness centrality identifies nodes that act as bridges or critical intermediaries within a network. It focuses on how often a specific node lies on the shortest paths between other nodes in the network. Nodes with high betweenness centrality have a greater influence on the flow of information or resources because they act as control points in the network.

Results show that four out of the central factors to the system appeared again: "*Continuous financial support available*", "*Favourable regulatory frameworks*", "*Poor consumer engagement*" and "*Support from industry and stakeholders*" (see Table 7). In addition, two other factors named: "*Adequate information and expertise*" and "*Available technology or innovation levels*" are also crucial and act as bridges or critical intermediaries within the system. These nodes frequently lie on the shortest paths between other nodes, giving them a significant role in information or resource flow. The last two factors (or nodes) might not have been identified as so central to the overall systems as the others, but their position within the network suggests they play a vital role in connecting different parts and facilitating information flow.

### 3.5.4 Scenario comparison

A next step involves simulating the system's behaviour and testing the defined scenarios. These scenarios aim to evaluate how specific conditions could influence the success of EDR policies. It's noteworthy that this analysis is conducted at the European level due to the limited data acquired at the individual country level. As outlined above and explained in detail in Annex. I: "***Scenarios definition***" one of the four scenarios includes an intervention impacting the most central elements identified based on the betweenness centrality analysis.

To simulate the system's behaviour effectively, the initial states of the system must first be defined and brought to a steady state. This initial state provides a baseline from which various conditions can be tested. In this study, initial estimates for the factor states were derived using proxies from the Gemini AI tool database[9]. It's important to note that this simulation serves as an illustration of potential effects, as no actual data were collected for the scenario analysis (refer to Annex. I - "***Simulation of system behaviour***" for more details). The choice of proxies was guided by their relevance and reliability, ensuring they represent key characteristics of the factors being analysed. While these proxies offer a structured approach to modelling, the findings should be interpreted with caution due to the inherent uncertainties associated with using estimated values. This simulation framework allows for the exploration of various scenarios, highlighting how different factors may interact and influence system behaviour over time. Future research could benefit from integrating real-world data to enhance the accuracy of the simulations and validate the assumptions made during the initial state definition.

An overview of the results can be seen in Figure 12, where values are displayed as percentage changes. Intervention 1, focusing on direct monetary support for industry and stakeholders, did not disclose any major changes across the factors in the system. Increasing the weight of the central systems with the most direct effect (as identified by betweenness centrality) by 25% also did not show any effect on the system outcomes. However, a set of conditions favouring the implementation and promotion of energy literacy decreased the negative effects related to the lack of appropriate group targeting (by 20%) and behavioural effects like rebounds (5.6%). In addition, a set of conditions aggravating the implementation of policy monitoring favoured the emergency of overlapping or opposed policies (25%) and decreased slightly the ease of implementation (2.9%). Lastly, and perhaps most notably, none of the simulated interventions resulted in significant changes in the success of EDR policies. This suggests that the system is already complex, robust, and stable, and that interventions targeting only specific nodes are insufficient to alter its final outcomes.

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9) Gemini: https://gemini.google.com

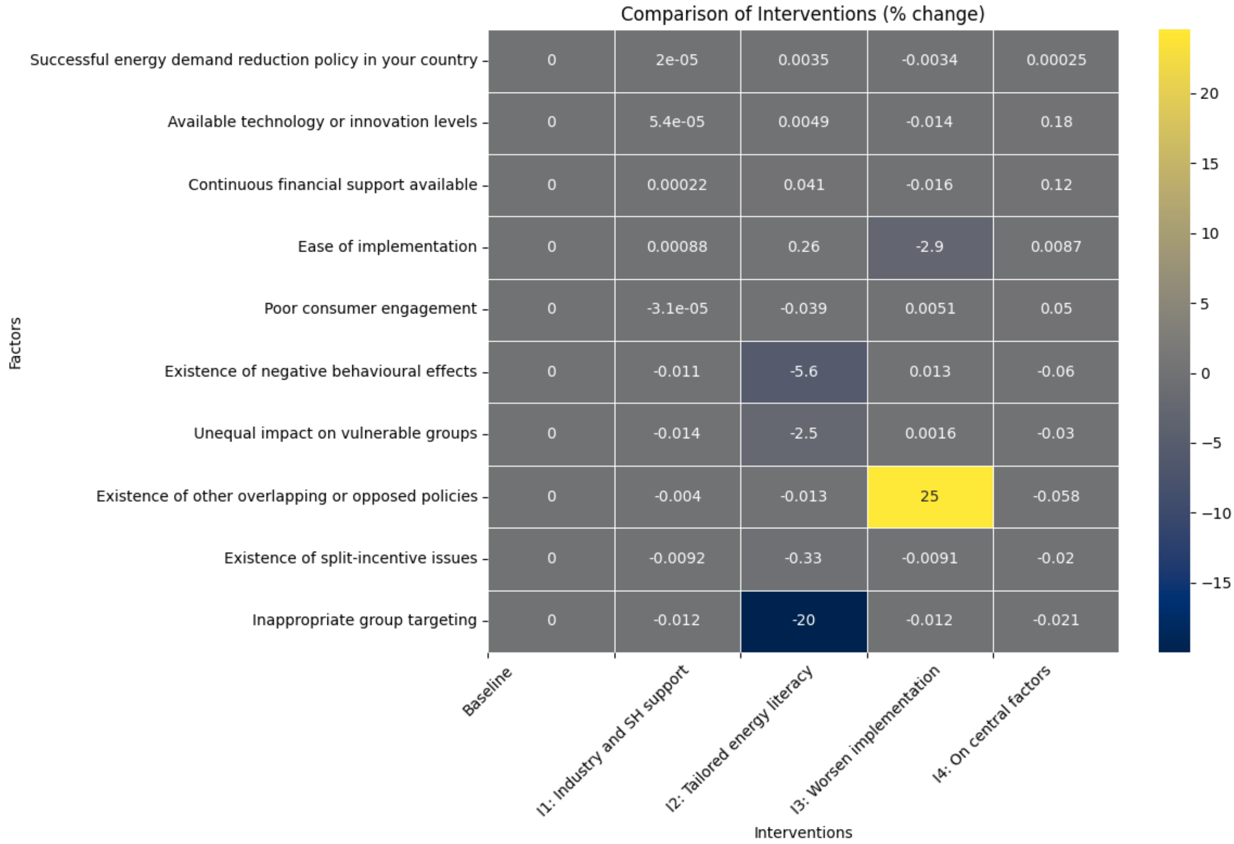



*Figure 12: Matrix showing the results of the simulated interventions. Values illustrate the direct effects of the different interventions over some of the factors that are part of the system.*

## 3.6 Discussion on the results

### 3.6.1 Overview and main observations

Fuzzy cognitive maps are used to capture expert knowledge on the national dynamics influencing the success of EDR policies. A defuzzification method based on fuzzy logic is then applied to transform linguistic terms, which indicated the causal relationships between the investigated factors, into numerical values representing the strength of these relationships within a weighted matrix. This analysis is performed at an aggregated model for all countries and individually for each country. The weighted values are subsequently used to compute centrality, identifying the most central factors within the system. Centrality measures, including degree, closeness, and betweenness, are applied to pinpoint influential nodes in the network.

Based on these measures, six factors emerge: "*Continuous financial support available*" "*Favourable regulatory frameworks*", "*Poor consumer engagement*", "*Ease of implementation*" "*Stable long-term policy with a clear mandate*" and "*Support from industry and stakeholders*". These factors are identified as central, indicating their importance within the system, although this does not necessarily mean they had the highest direct impact on the success of EDR policies. This finding aligns with other studies on energy policy effectiveness; for instance, Sorrell et al. (2015) emphasized the importance of long-term policy stability and regulatory frameworks (Sorrell, 2015), while Moe et al. (2016) highlighted stakeholder support and consumer engagement as critical components for successful energy transitions (Moe, 2016).

The analysis also shows a high correspondence between closeness centrality and degree centrality. Betweenness centrality highlighted the presence of two additional nodes acting as critical intermediaries within the network. Factors deemed central by degree centrality, such as "*Continuous financial support available*" "*Favourable regulatory frameworks*", "*Poor consumer engagement*" and "*Support from industry and stakeholders*" were also significant in betweenness centrality. Moreover, "*Adequate information and expertise*" and "*Available technology or innovation levels*" were crucial for facilitating information flows.

These results suggest that these factors are crucial at the aggregated level (i.e., across EU countries) for the success of energy demand reduction policies.

The results on the intervention simulated showed that neither direct monetary support for Industry and stakeholders (Intervention 1) nor increasing central system weights by 25% (Intervention 4) significantly changed system factors. However, tailored energy literacy (Intervention 2) decreased the impact of both inappropriate group targeting and behavioural effects (e.g., rebounds). Worsening policy monitoring (Intervention 3) also slightly hindered the implementation of these policies and increased the overlapping effects with other policies. Overall, no interventions significantly affected EDR policy success, indicating the system's robustness and stability —a conclusion that echoes findings from complex systems research in energy policy, such as those by Mutingi et al., 2017, which noted that energy systems exhibit resilience to interventions due to their complex interconnected nature. This outcome highlights the difficulty in influencing the success of EDR policies, which heavily depend on complex systemic dynamics. It suggests the need for more detailed models that minimize aggregation, such as focusing on specific sectors like buildings, particular industries, and transportation.

### 3.6.2 Policy Implications

The findings from this study underscore the complexity of transforming a robust and intricate system like EDR through reliance on minor interventions. While some factors were identified as central—such as continuous financial support, favourable regulatory frameworks, and consumer engagement—changes to these factors did not significantly influence the overall success of EDR policies. Nonetheless, some interventions tested yielded interesting results. For instance, tailored energy literacy programs demonstrated a significant role in mitigating negative outcomes associated with inappropriate targeting and behavioural rebounds, providing practical strategies for implementing the study's insights. Given its importance in the results, this intervention is explored further in the next section.

However, the results also highlight the limitations of minor policy adjustments, which often yield limited impacts. For example, small changes, such as slight increases in financial incentives or minor regulatory tweaks, may not substantially influence overall energy consumption if not accompanied by broader systemic considerations. This suggests that addressing a single factor in isolation—without acknowledging its interconnections with other elements—can lead to minimal overall change. The intricate interplay of factors within energy systems—characterized by variable interdependencies and feedback loops—can undermine the intended effects of any given intervention.

This complexity underscores the necessity of adopting a **systems-based approach to policymaking**. Policymakers must consider the interconnected nature of these factors and the overarching system dynamics when designing interventions. Given the robustness of the energy system, targeted interventions may require complementary broader systemic changes to effectively influence EDR outcomes.

A relevant example of this approach is Denmark's integrated energy (Danish ministry of climate, energy and utilities, 2019)., which combines wind energy expansion, district heating, and energy efficiency improvements within a cohesive framework. The strategy not only focuses on technological advancements but also emphasizes local community engagement, economic incentives, and grid enhancements tailored to regional needs. Its success lies in its holistic approach, aligning national goals with regional capacities and challenges while fostering active participation from local stakeholders. For instance, Denmark's focus on community-owned wind farms leverages local involvement and investment, leading to higher acceptance and more effective energy transition outcomes.

It is crucial to recognize that the scope of this study is limited by the small number of experts consulted, meaning that the findings should be interpreted with caution. Furthermore, the comparative analysis of the interviewed countries, as detailed in the section "*Country Comparison (Additional Analysis)*" in Annex II, highlights the need for country-specific strategies that reflect local conditions.

# 4 Tailoring policies through energy literacy and user profiles

## 4.1 Behavioural determinants and EDM

The management of energy demand has been a central focus of energy policy since the 1970s, driven largely by the introduction of regulations, standards, and more recently, strategies designed to adjust energy market (Goldemberg et al., 2000). During the 1980s, policymakers began using the term "energy conservation" to describe efforts to manage energy demand through various regulatory measures.

Since the 2000s, the integration of social science into energy research has emerged as crucial for comprehensively understanding the human dimensions involved in sustainable energy transitions. This interdisciplinary approach enables researchers to gain valuable insights into the factors influencing energy behaviours, the acceptability of energy policies, and the necessary changes in energy systems (Steg et al., 2015). By examining these elements, it becomes possible to assess the broader societal impacts and implications of energy-related decisions and policies (Sovacool et al., 2015).

Social sciences play a significant role in understanding the social acceptance of renewable energy innovations and energy consumption (Wüstenhagen et al., 2007). They provide insights into various factors that influence attitudes, values, and ultimately behaviours towards renewable energy. Some of the factors that social sciences can help discern are environmental awareness, perceptions of benefits and drawbacks, trust (i.e., in institutions), acceptance, or community engagement and motivation amongst others.

When policymakers have a better grasp of these factors, strategies can be developed to increase social acceptance and accelerate the transition to renewable energy. Social acceptance of renewable energy technologies is heavily influenced by values and norms. Individuals and communities with strong environmental values are more likely to support renewable energy initiatives. Social norms also play a crucial role; if renewable energy adoption is perceived as a societal norm, acceptance tends to be higher. Trust in institutions, such as government and industry, is another critical factor. Public trust in these entities significantly affects acceptance, making transparency, fairness, and community engagement essential for fostering support. Information and awareness are also pivotal in shaping social acceptance. Public understanding of the benefits and limitations of renewable energy can influence their acceptance, as misinformation or lack of knowledge often leads to resistance. The cultural and socioeconomic context further impacts acceptance. Societies that are more open to technological change may be more willing to embrace renewable energy. Additionally, poor communities might prioritize immediate economic concerns over environmental benefits, affecting their support for renewable energy initiatives. By examining norms, attitudes, values, as well as other perceived environmental (product, technology, climate) attributes, and governance structures, social science can provide insights into how different factors influence the use and consumption energy technologies (Noppers et al., 2019). Furthermore, transitioning to renewable energy involves understanding the trade-offs and negative aspects that come with it. These can include adjusting to the intermittent nature of some renewable energy sources, accepting new infrastructure such as wind turbines or solar panels in local communities, or changing energy consumption habits to align with renewable energy production (Devine-Wright, 2005; Sovacool, 2009).

Thus, understanding energy behaviours from a psycho-behavioural perspective can help bring energy policies to the forefront within energy research, emphasizing the interconnectedness between various policy domains and their impacts on energy systems (Cox et al., 2019). By bridging the gap between energy research and behaviour, energy demand reduction, energy poverty, and the determinants of energy consumption can be addressed in a more targeted way (European Energy Research Alliance, 2024; Royston et al., 2018) allowing for a more comprehensive analysis of energy systems and policy interventions (Strielkowski, 2021)

The importance of considering determinants of behaviour when selecting interventions for pro-environmental behaviour change is discussed by (van Valkengoed et al., 2022). It is highlighted that interventions are more effective when key determinants of behaviour are targeted. A similar perspective is shared (Battaglia, 2021). A classification system is proposed by the authors, which links six types of interventions to 13 determinants of environmental behaviour. The determinants, including knowledge, risk perception, negative affect towards environmental problems, problem awareness, ascription of responsibility, personal norms, self-focused emotions, attitudes towards behaviour, descriptive norms, injunctive norms, self-efficacy, outcome efficacy, and environmental self-identity, are included. The interventions, which include information provision, commitment, feedback, incentives, goal setting, and choice architecture, are also detailed.

## 4.2 Consumer segmentation & profiling

Consumer segmentation started in the marketing and branding fields, to understand the diverse characteristics and preferences of consumers and deals with grouping consumers, or potential consumers, based on their shared characteristics. Several studies have investigated the evolution of consumer segmentation frameworks, emphasizing the significance of considering consumers' backgrounds, market history, and cultural aspects in developing meaningful segments (Kaufmann et al., 2012; Norman-Acevedo et al., 2020; Venkatraman et al., 2012). This segmentation, which in branding and marketing is conducted with consumer research (demographics, customer satisfaction, preferences) aims at creating marketing strategies to better understanding consumers, and hence at developing marketing and sales strategies that are tailored to reach out the specific the segments in the most suitable way.

To create segments or profiles of customers, several techniques exist, as shown in table 8 . Model-based segmentation methods like REBUS-PLS have emerged as effective tools for capturing heterogeneous consumer behaviour (Mehmetoglu, 2011). Benefit segmentation has also been recognized as an adequate approach to market segmentation, focusing on the benefits sought by consumers rather than just descriptive factors (Rao & Wang, 1995). Consumer-revealed segmentation analysis based on natural associations observed during data analysis has been highlighted as an effective way to identify consumer segments (Aljukhadar & Senecal, 2011). Other techniques, such as statistical clustering, specifically hierarchical clustering or two-step clustering have been utilized for segmentation, allowing for the grouping of consumers with similar characteristics or behaviours into groups (Arli et al., 2019; Chawla & Joshi, 2021; Tkaczynski & Rundle-Thiele, 2013).

*Table 8: Consumer Segmentation Techniques*

| Technique | Description |
|---|---|
| REBUS-PLS | Model-based segmentation to capture heterogeneous consumer behaviour. |
| Benefit Segmentation | Focus on benefits sought by consumers rather than just descriptive factors. |
| Consumer-Revealed Segmentation | Analysis based on natural associations during data analysis. |
| Statistical Clustering (Hierarchical or Two-Step Clustering) | Grouping consumers with similar characteristics or behaviours. |

These methods enable marketers to understand consumer preferences, behaviours, and needs more effectively, leading to targeted marketing strategies.

Table 9 shows factors influencing energy behaviours: in energy demand and consumption, it has been shown that behavioural determinants such as intentions, attitudes, and values vary amongst people, influencing the way and amounts in which they consume energy. Previous studies have indicated that individual characteristics such as involvement, perceptions, and values significantly impact sustainable consumption patterns and help bridge the gap between attitudes and behavioural intentions (Ben & Steemers, 2018, 2020). Cultural values have been identified as key predictors of energy-saving attitudes and intentions, emphasizing their role in influencing energy conservation behaviours among urban residents (Duong, 2022).

*Table 9: Constructs influencing energy conservation behaviours.*

| Constructs | Influence on energy conservation |
|---|---|
| Cultural Values | Key predictor of energy-saving attitudes and intentions. |
| Attitudes Toward Energy-Saving | Indirect relationship with household energy consumption; impacted by individual intentions. |
| Awareness and Compatibility | Predictors of attitudes toward energy conservation and sustainable intentions in the electric power industry. |
| Comfort Preferences in Rural Areas | Directly influence intentions to save energy, affecting overall energy consumption behaviours. |

Studies have shown that attitudes towards energy-saving have an indirect relationship with household energy consumption, with intentions playing a role (Zhang et al., 2021). Additionally, research in the electric power industry has identified awareness, compatibility, perceived value, resistance to change, and actual gain as predictors of attitudes towards energy conservation and sustainable behavioural intentions (Habib et al., 2010). In rural areas, residents' attitudes towards comfort preferences directly influence their intentions to save energy, thereby impacting energy consumption behaviours (Jiang et al., 2021).

These types of studies highlight the complexity of consumer behaviours concerning energy consumption and the interplay between values, attitudes, and intentions, and how policy makers can make use of such behavioural determinants to create segments and profiles of consumers for more successful, tailored policy instruments. A proof of concept of such policy tailoring is presented in the following sections.

## 4.3 Importance of profiling in EDM

Emerging research suggests that when it comes to energy consumption, behavioural and psychological factors may wield a more significant influence than socio-demographic factors. Frederiks, Stenner, and Hobman (2015) conducted a comprehensive review exploring two overarching categories of variables that could potentially account for variations in energy consumption and conservation: socio-demographic factors and psychological factors (Frederiks et al., 2015). However, their findings revealed that the empirical evidence regarding the impact of these variables has been inconsistent and inconclusive thus far. In a separate study, Carrus et al. (2021) employed a meta-analytical approach to evaluate the strength of associations between various individual variables (such as attitudes, intentions, values, awareness, and emotions) and energy-saving behavioural intentions and behaviours (Carrus et al., 2021). Their results indicated that these individual-level predictors demonstrated positive and moderate associations with energy-saving outcomes, with emotional factors exhibiting the most pronounced effects and pro-environmental values showing relatively smaller to moderate effects. Moreover, Luo, Li, and Sun (2022) discovered that functional, emotional, conditional, and green values exerted a positive influence on consumer satisfaction, thereby fostering the intention to purchase energy-saving products (Luo et al., 2022). In this case, demographic factors such as educational background, household income, and age did not exhibit discernible effects on behavioural intentions. Another study conducted by Iyiola and Mewomo (2022) identified five critical factors that impact occupants' energy use behaviour: awareness factors, personal factors, socio-demographic factors, management factors, and motivational factors. These findings highlight the pressing need to address the factors that influence occupants' energy use behaviour, given the challenges faced by the environment and the ecosystem (Iyiola & Mewomo, 2023).

Several researchers have used behavioural and psychological parameters to segment and tailor design strategies for energy consumption reduction or to better understand the target groups. In a study conducted by Ipsos (2019), in Belgium, the Flemish population was categorized into five segments based on their attitudes towards energy and energy-saving measures. The segments include Indifferents, representing 17% of households, who show little concern for energy consumption and believe the government should play a significant role. Passives, accounting for 24% of households, consider energy saving important but prioritize comfort improvement. Relativists comprising 18% of the population, value energy saving but prioritize other societal problems. Rationally Motivated, making up 20% of households, are highly concerned with energy and climate issues and support government contributions. Finally, Autonomously Motivated, representing 21% of households, deeply care about climate issues, highly value energy saving, and favour government enforcement (IPSOS, 2019). Other studies have conducted segmentation in the built environment to better understand preferences and behaviours of different types of occupants, to design guidelines and strategies for improved energy consumption or health. Eijkelenboom & Bluyssen (2020) conducted studies on the health and comfort of staff in outpatient areas of hospitals in the Netherlands. They also profiled outpatient staff based on their self-reported comfort and preferences of indoor environmental quality and social comfort in six hospitals (Eijkelenboom & Bluyssen, 2020). In another study, they researched students' self-reported health and psychosocial status at home before and during COVID-19. They also profiled office workers based on their self-reported preferences of indoor environmental quality and psychosocial comfort at their workplace during COVID-19 (Ortiz & Bluyssen, 2022).

Understanding these segments is crucial for effective energy demand management for several reasons. Different segments have varying attitudes and behaviours towards energy consumption and saving. By identifying these segments, policymakers and energy providers can tailor their strategies, programs, and communication efforts to effectively engage and motivate each group. This targeted approach increases the likelihood of successful energy demand management initiatives. Furthermore, knowing the specific motivations and preferences of each segment allows for the design of customized interventions. For example, some segments may respond well to financial incentives or subsidies, while others may be more motivated by environmental concerns or social responsibility. By aligning interventions with the values and needs of each segment, energy demand management efforts can be more persuasive and influential. Finally, understanding these segments helps identify barriers and challenges faced by different groups. It allows policymakers to address specific concerns and provide the necessary support or resources where needed. For instance, if a segment requires more information or guidance on energy-saving measures, targeted educational campaigns or assistance programs can be developed (Palm & Eriksson, 2018).

**Box 4 From Psychographics to Policy: Photovoltaics in Sweden**

Research conducted in Sweden explored the factors influencing households' decisions to adopt PVs. This study revealed that **economic motivations alone were insufficient to drive adoption**. Instead, **social factors**, such as the desire to align with community norms and values, **played a significant role**. The study involved interviews with 58 households, revealing that many adopters were motivated by a combination of environmental concerns, the desire for energy independence, and social influence from neighbours and peers. These insights helped **shape policy recommendations**, suggesting that promoting solar panels in Sweden should focus not just on economic incentives but also on enhancing **social acceptance and leveraging community networks** to spread positive experiences with PV systems. For instance, informational campaigns highlighting local success stories and community benefits of solar energy were recommended to improve adoption rates.

## 4.4 Results: Profiles of behavioural determinants

A questionnaire based on the Technology Acceptance Model was distributed to a panel of respondents in December 2023, with the aim of gaining insights into behavioural constructs related to the acceptance of electric vehicles in two countries, namely **Portugal and Norway**. Data was gathered in November 2023, through a panel with Dynata, and with the collaboration of Efthymios Atlsitsiadis from the Copenhagen Business School.

The collected data were analysed using clustering analysis to identify user profiles that differ in their behavioural determinants regarding electric vehicles adoption. For details of the clustering process, please refer to Annex I and II. The clustering was based on three behavioural determinants: attitudes towards electric vehicles, values concerning electric vehicles, and intentions to use and drive EVs, and followed the procedure as outline by a number of authors profiling occupants based on behavioural determinants (Eijkelenboom & Bluyssen, 2020; Ortiz & Bluyssen, 2019, 2022; D. Zhang et al., 2019).

Values, intentions, and attitudes are three behavioural determinants that were chosen as it is proven they play an important role in shaping individuals' behaviours, especially in the domains of sustainability behaviours (Ajzen, 1985, 1991; Fishbein & Ajzen, 1975). Theoretical frameworks such as the Theory of Reasoned Action (TRA), and its extension, the Theory of Planned Behaviour (TPB), are two of the most widely used behavioural models in energy conservation, energy transition, environmental behaviours (Ajzen, 1985, 1991; Fishbein & Ajzen, 1975). This is shown in table 10.

*Table 10: Key behavioural determinants in adoption.*

| Determinant | Description |
|---|---|
| Attitudes | Positive or negative evaluations of EVs and their adoption. |
| Values | Alignment of EVs with environmental and personal values. |
| Intentions | Likelihood of adopting and using EVs based on motivational factors. |
| Perceptions | Views on EV safety, ease of use, and the benefits of adopting electric vehicles. |

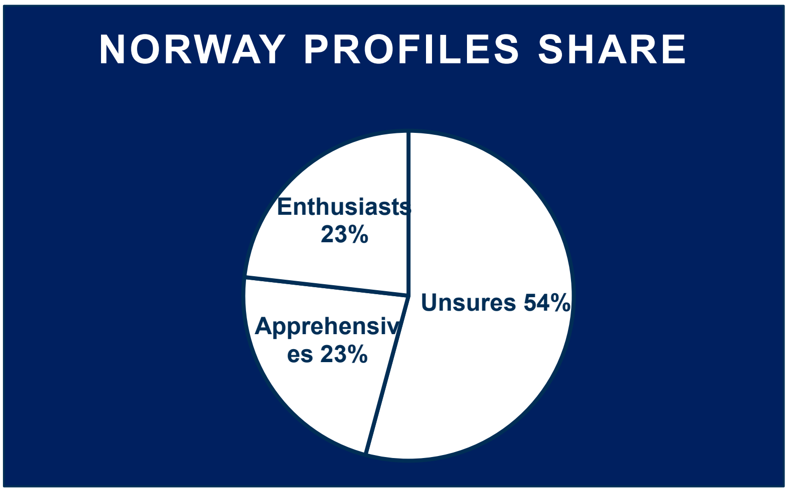
Intentions, according to the TRA, are defined as "assumed to capture motivational factors that influence a behaviour", while also indicating the amount of effort an individual is ready to provide to achieve a behaviour. Attitudes are defined as a "relatively enduring organization of beliefs, feelings, and behavioural tendencies towards socially significant objects, groups, events or symbols." (Hogg & Vaughan, 2005). Finally, **values** are described as assessments of conceptual ideals (duty, morality) in relation to their significance as fundamental principles that guide individuals in their lives (Schwartz, 1992).

Profiles are linked to intentions, attitudes, and values by analysing how individuals perceive and respond to behaviours like adopting renewable technologies. Using the behavioural model of the theory of Technology Acceptance Model (TAM), data was collected through a survey measuring these constructs and then apply clustering analysis to group individuals with similar responses. This data-driven approach creates distinct profiles based on similarities in attitudes (positive/negative), values (alignment with environmental goals), and intentions (likelihood of adopting behaviour).

Table 11 shows, in the Portuguese sample, **four profiles** emerged (EV Advocate, EV Skeptic, EV Potential Adopter, and EV Undecided), and for the Norwegian sample, **three profiles** emerged (EV Apprehensive, EV Unsure, and EV Enthusiast). Below is a description of these profiles.

*Table 11:Profiles of behavioural determinants (Portugal and Norway).*

| Determinant | Profile | Description |
|---|---|---|
| Portugal | EV Advocate | Strongly supports EVs; sees driving EVs as morally right and a reflection of personal values. |
| Portugal | EV Sceptic | Holds negative attitudes and low intentions toward EVs; needs practical benefits to consider EV adoption. |
| Portugal | EV Potential Adopter | Open to EVs but not fully committed; perceives benefits but lacks strong moral alignment. |
| Portugal | EV Undecided | Neutral towards EVs; does not see them as a priority or aligned with personal values. |
| Norway | EV Unsure | Low to moderate intentions but positive attitudes; does not see EVs aligning with values. |
| Norway | EV Apprehensive | Negative attitudes and low intentions; perceives EVs as difficult to maintain and use. |
| Norway | EV Enthusiast | Strong supporter of EVs with high intentions; perceives EVs as safe, environmentally friendly, and easy to use. |



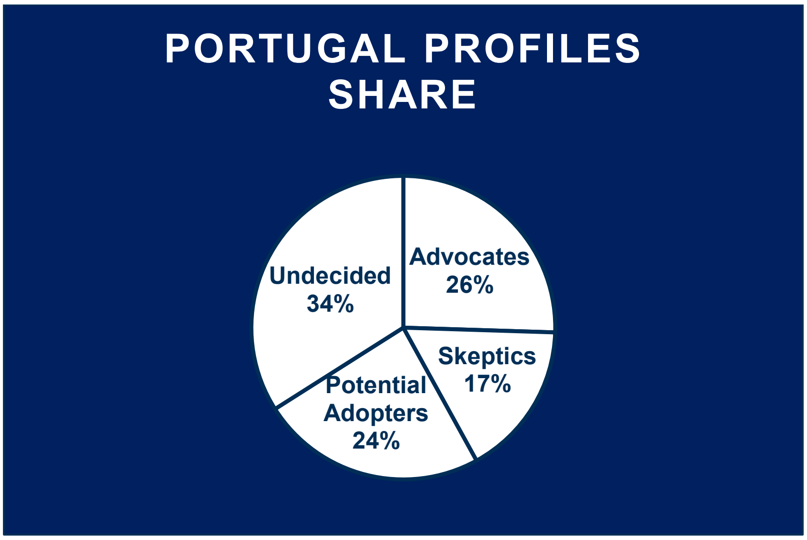




*Figure 13:Distribution of Profiles for Portugal and Norway.*

### 4.4.1 Portugal

**Cluster 1, EV Advocate:**

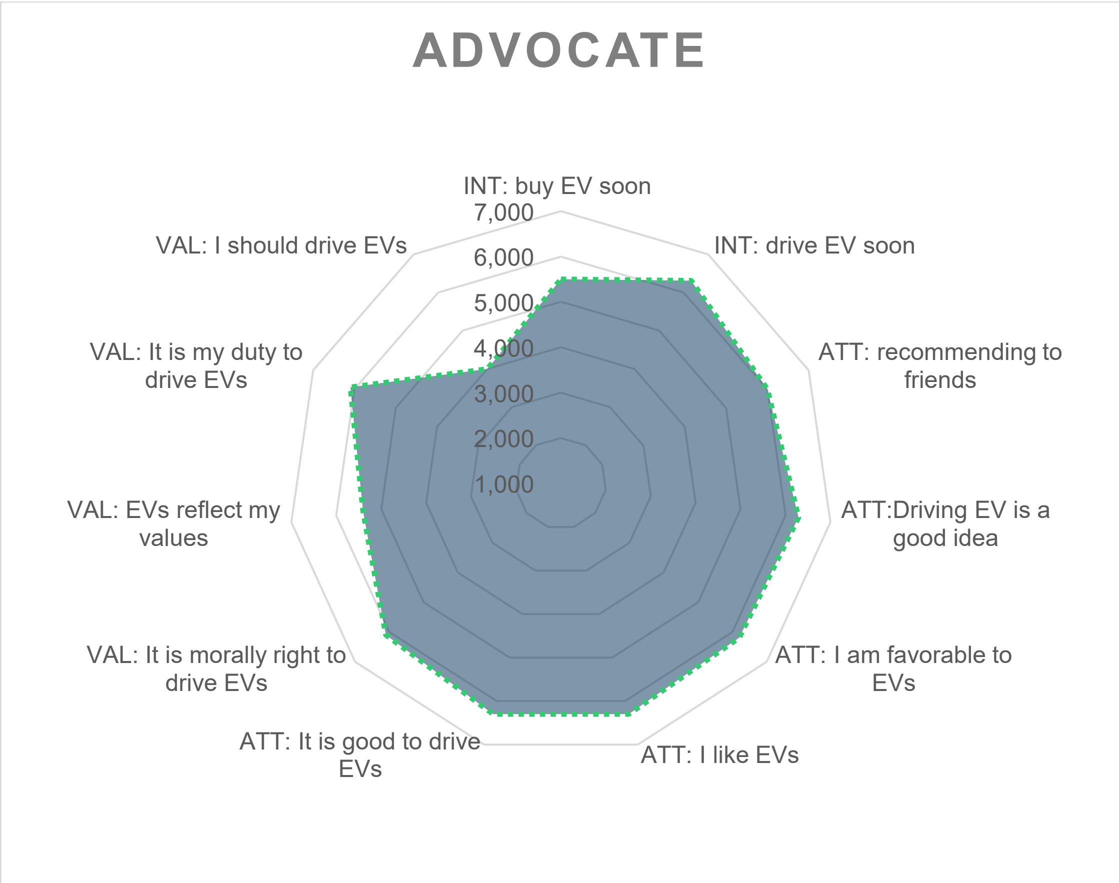



*Figure 14: EV Advocates. Ratings on a scale from 1= completely disagree, to 7=completely agree. (ATT: constructs belonging to attitudes, VAL, construct belonging to Values, INT, constructs belonging to Intentions).*

The advocates profile (Figure 13) profile represents individuals who strongly support EVs both in intention and attitude. Their positive attitudes towards EVs align with their high intentions to buy and drive EVs soon. They see driving EVs as a good idea, morally right, and even a duty. The EV Advocate is likely to **recommend EVs to friends and see EVs as reflecting their personal values**. However, they might have some hesitation ("I should drive EVs" score of only 4.0) indicating they **might need more convincing or practical reasons to fully commit.** In terms of perceptions, they see EVs as safer, offering a dynamic driving experience, and appreciate their environmental benefits. They also find EVs easy to use, maintain, and charge, with a good understanding of EV technology.

## Cluster 2, the EV Sceptic:

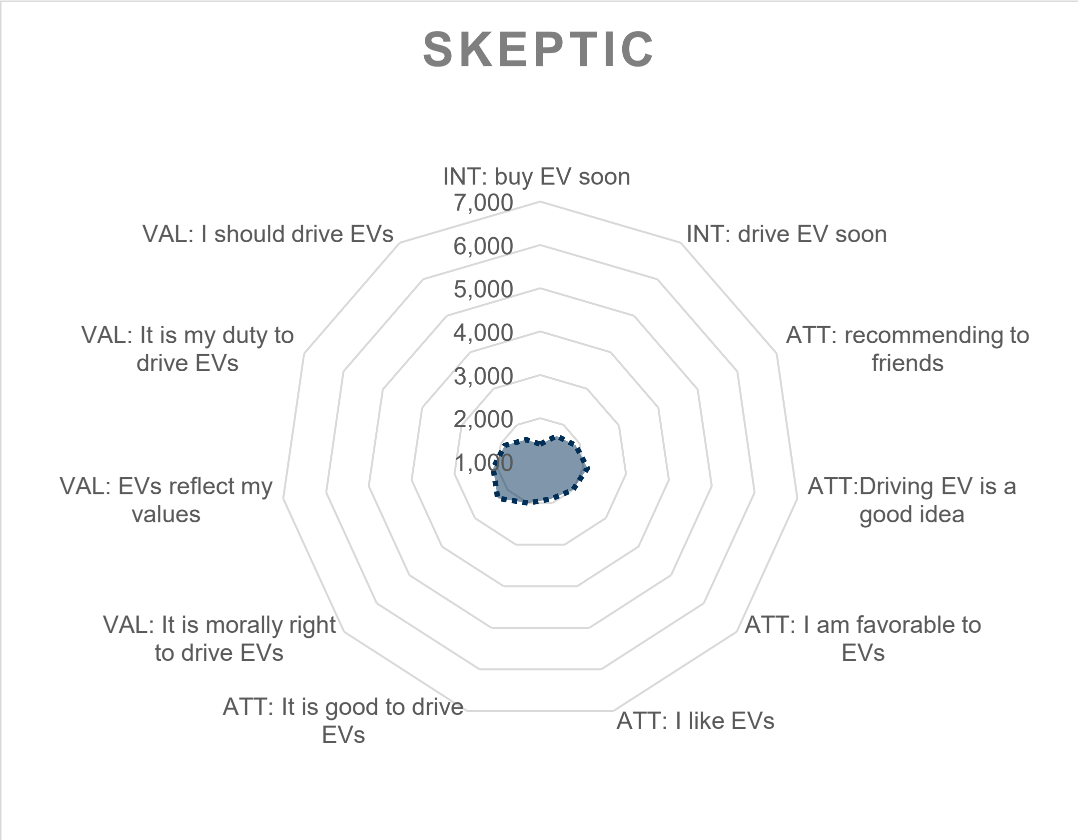



*Figure 15: EV Sceptics. Ratings on a scale from 1= completely disagree, to 7=completely agree. (ATT: constructs belonging to attitudes, VAL, construct belonging to Values, INT, constructs belonging to Intentions).*

The Skeptic profile (Figure 15) who holds negative attitudes and low intentions towards EVs. They are hesitant about EVs, seeing them as not aligning with their values or beliefs. This group is **unlikely to recommend EVs** to friends, and they do not see driving EVs as a good idea. They might need **significant persuasion or practical benefits to consider EV adoption**. Additionally, they perceive EVs as less safe, less dynamic, and more challenging to use and maintain compared to the other profiles.

## Cluster 3, the Potential Adopter:

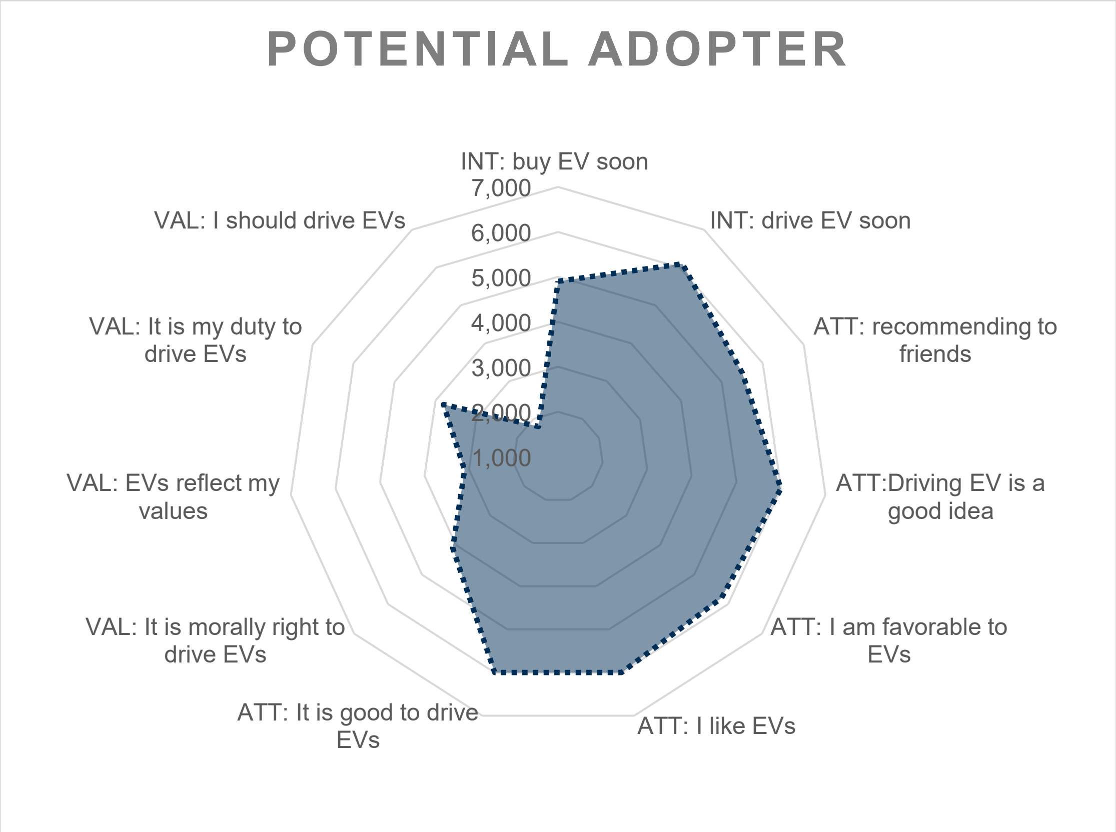



*Figure 16: EV Potential Adopters. Ratings on a scale from 1= completely disagree, to 7=completely agree. (ATT: constructs belonging to attitudes, VAL, construct belonging to Values, INT, constructs belonging to Intentions).*

The Potential Adopter (figure 16) profile who is **open to the idea of EVs but is not fully committed yet**. The Potential Adopter intends to drive and potentially buy EVs soon (6.1; 4.9). They see driving EVs as a good idea and are favourable towards EVs (6.0), but they are not fully convinced that EVs align with their values (3.1) or that is morally right to do so (4.1). They might need more information or persuasion to fully embrace EVs, as they are not strongly driven by a sense of duty or moral obligation. However, they perceive EVs as relatively easy to use and maintain, with benefits such as lower emissions and potential cost savings being attractive to them.

Cluster 4, the EV Undecided:

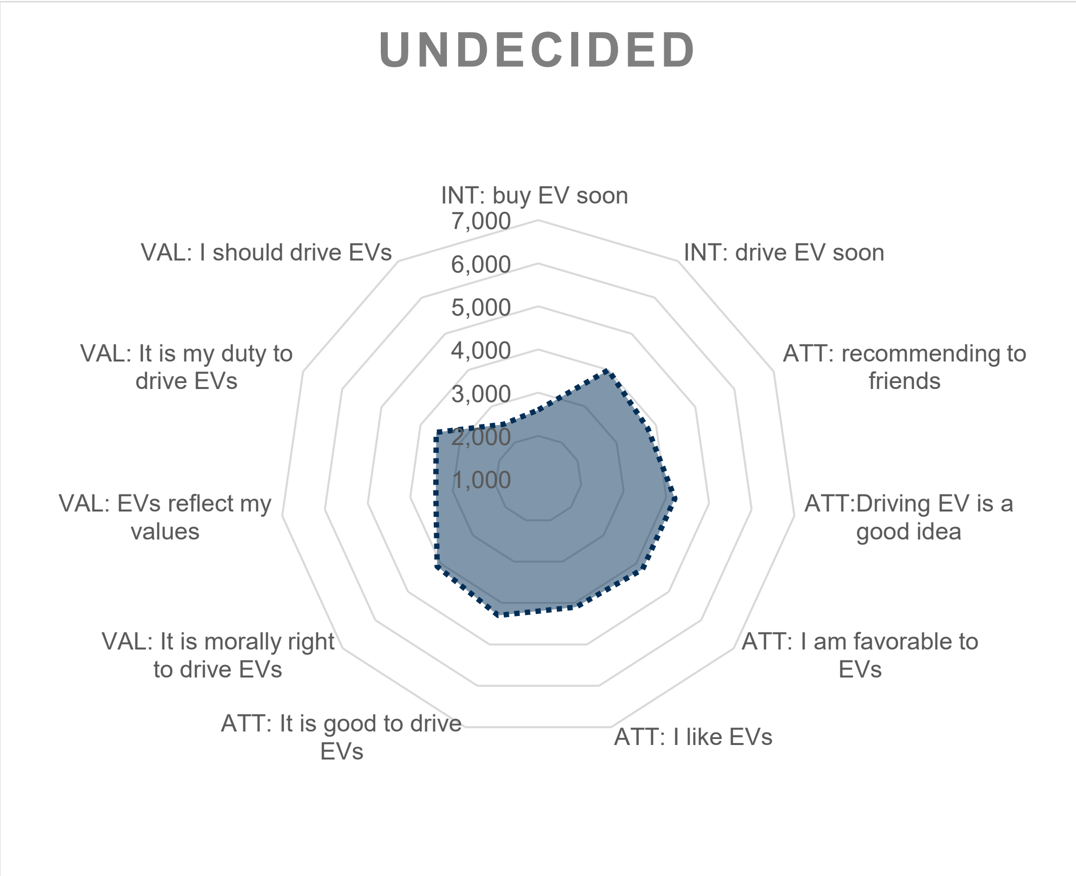



*Figure 17: EV Undecided. Ratings on a scale from 1= completely disagree, to 7=completely agree. (ATT: constructs belonging to attitudes, VAL, construct belonging to Values, INT, constructs belonging to Intentions).*

The Undecided (figure 17) profile who holds **neutral attitudes and intentions towards EVs**. The EV Indifferent is not strongly convinced about the benefits or necessity of EVs. While they don't strongly oppose EVs, they also don't see them as a priority or alignment with their values. They **might need more information or practical reasons to consider EV adoption**, as they are not driven by a sense of moral obligation or duty to drive EVs. They perceive EVs as moderately easy to use and maintain, but they have concerns about charging infrastructure and the time it takes to charge.

### 4.4.2 Norway

Cluster 1, EV Unsure:

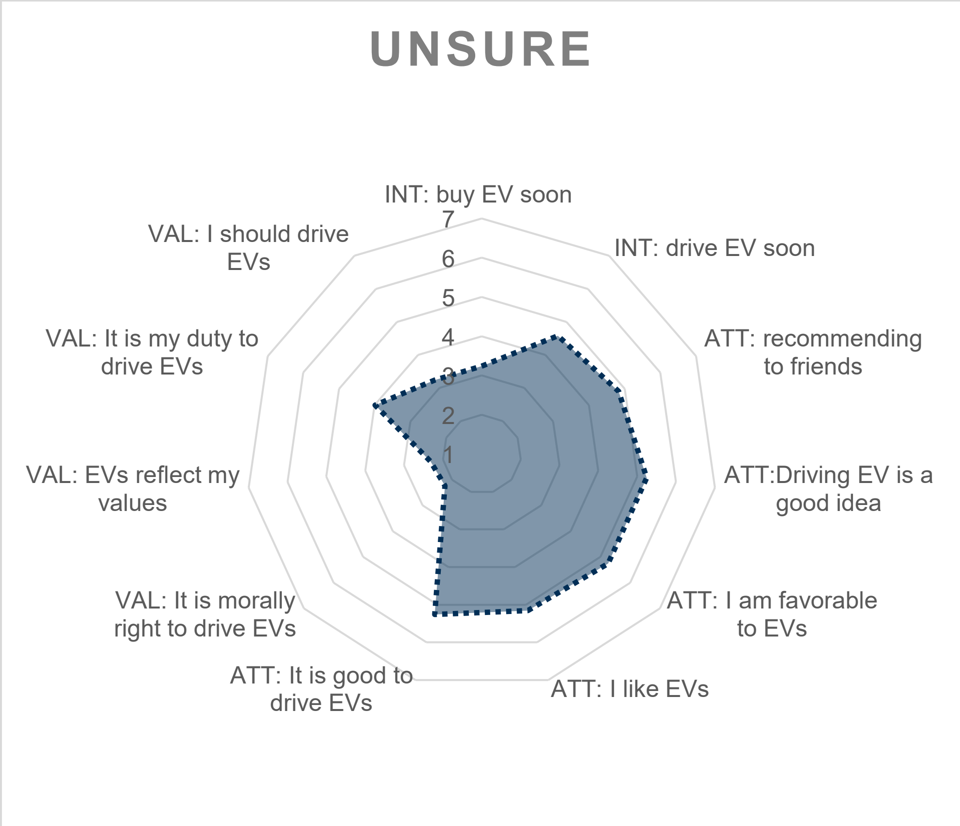



*Figure 18:EV Unsure. Ratings on a scale from 1= completely disagree, to 7=completely agree. (ATT: constructs belonging to attitudes, VAL, construct belonging to Values, INT, constructs belonging to Intentions).*

The Unsure (Figure 18) profile shows **low to moderate intentions to buy an EVs soon** (3.2). however, their attitudes tend to be slightly positive towards EVs, they would recommend EVs (4.8) and having and generally favourable attitude (5.2). The Unsure has an unfavourable view on EVs, considering misaligned with their all their values, whether morals and duties. **Perceived ease of use and usefulness of EVs are also high for this group**, believing EVs are safer, offer a dynamic driving experience, drive quietly, and can be charged with renewable energy. They also perceive EVs as cost-effective, easy to drive, and not overly complex in terms of maintenance and technology.

**Cluster 2, EV Apprehensive:**

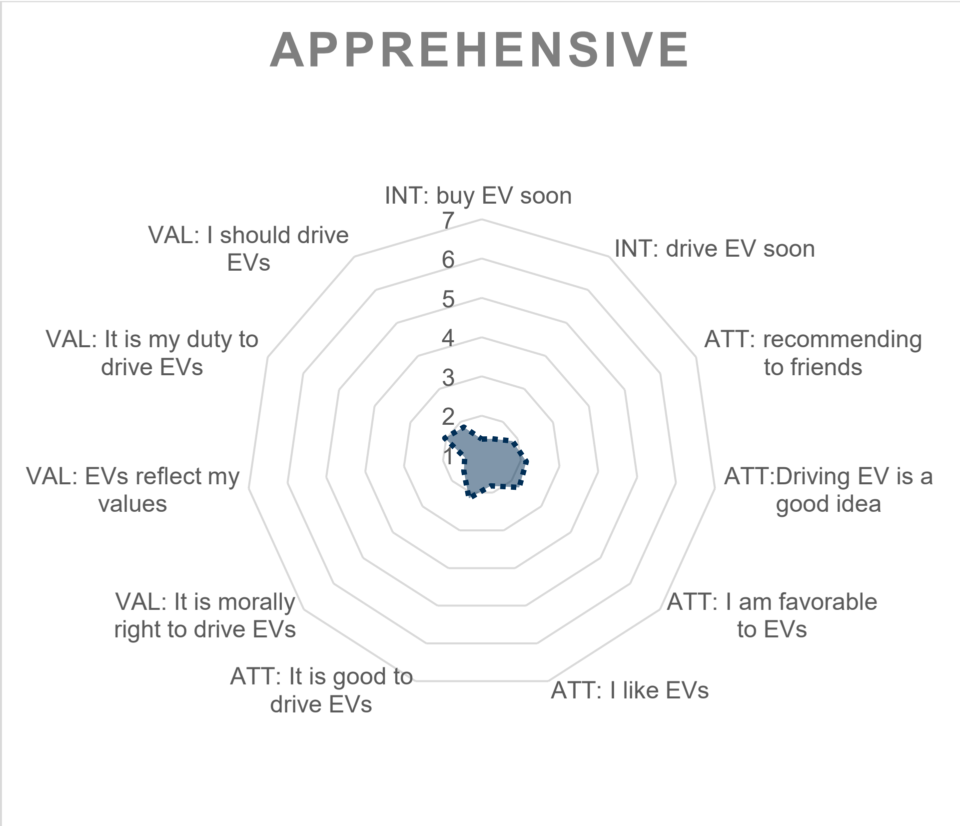



*Figure 19: EV Apprehensive. Ratings on a scale from 1= completely disagree, to 7=completely agree. (ATT: constructs belonging to attitudes, VAL, construct belonging to Values, INT, constructs belonging to Intentions)*

The Apprehensive (Figure 19) profile shows **low intentions to buy and drive EVs soon** (1.4), with mean scores at the lower end of the scale. They have more negative attitudes towards EVs, indicating they are less likely to recommend EVs to friends or see them as beneficial (1.8). The Apprehensives do not see EVs as aligning with or reflecting favourably on their values. Usefulness of EVs is generally low for this group, believing that EVs are not necessarily safer, do not offer a dynamic driving experience, and are not significantly cheaper to maintain or charge. They also find charging and operating an EV to be more complex and time-consuming.

## Cluster 3 EV Enthusiast:

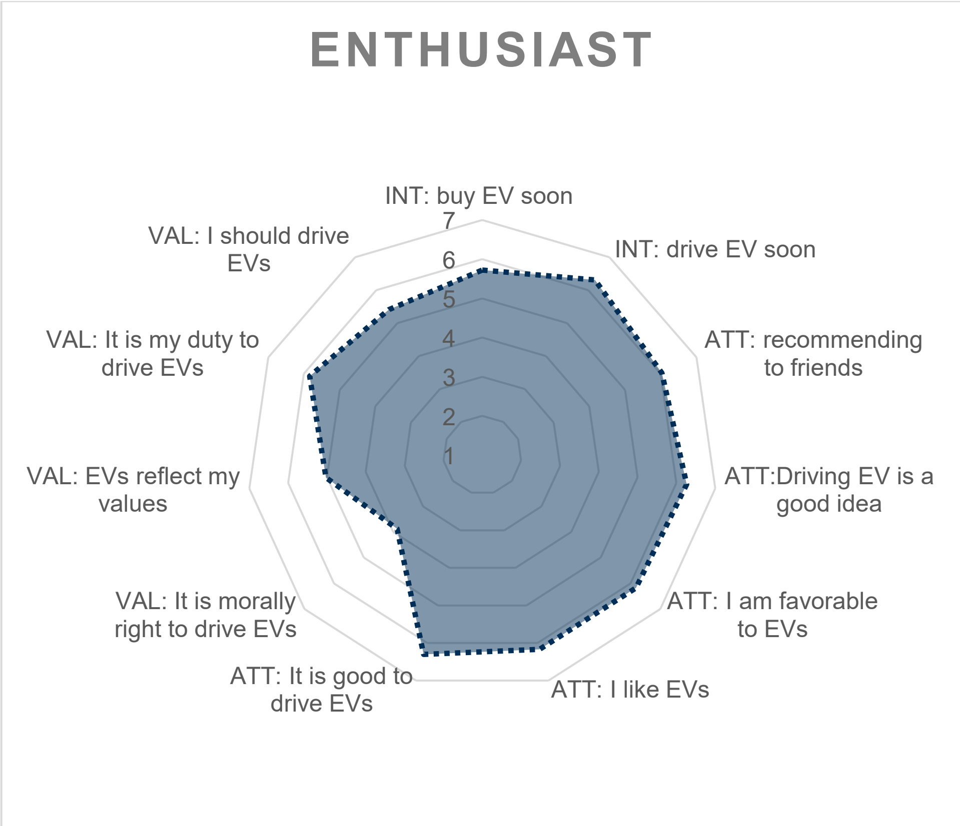



*Figure 20: EV Enthusiast. Ratings on a scale from 1= completely disagree, to 7=completely agree. (ATT: constructs belonging to attitudes, VAL, construct belonging to Values, INT, constructs belonging to Intentions).*

The Enthusiast profile (Figure 20) who is a **strong supporter and early adopter** of electric vehicles, with high intentions to buy and drive EVs soon (5.7; 6.3). They exhibit extremely positive attitudes towards EVs, being very likely to recommend them to friends and seeing driving an EV as a highly favourable and beneficial idea (6.2). This persona deeply believes in the moral and values-aligned aspect of driving EVs, feeling it is not only their duty but also something they should actively pursue. Perceived Ease of Use and Usefulness of EVs are exceptionally high for this group, believing that EVs are safer, offer a dynamic and quiet driving experience, do not produce harmful emissions, and can be cost-effective in terms of maintenance and refuelling. They also have a strong belief that EVs provide tax reliefs, can be charged with renewable energy, and find the process of owning and operating an EV to be straightforward and easy. This persona may have some concerns about charging infrastructure, but they are generally confident that adapting their lifestyle to EV charging will not be a significant hurdle.

## 4.5 Science-based strategies to change behavioural determinants.

The profiles to focus on for increasing EV use in both countries, are the Apprehensive, the Unsure, the Potential Adopter, the Skeptic, and the Undecided. These profiles have the common features of tending to have more negative attitudes towards EV, more negative values, and lower intentions to use EVs. Therefore, **policy strategies should focus on these behavioural determinants.** Table 12 summarizes the key strategies for change, which are explained in the next paragraphs.

*Table 12: Key policy strategies for changing EV adoption.*

| Construct tackled | Science-based change strategy* | Example instrument | Portugal concerned Profiles | Norway concerned Profiles |
|---|---|---|---|---|
| **Negative attitudes** | Positive communication strategies.<br>Positive regulation.<br>Extrinsic motivation.<br>Problem solving instructional strategies. | Targeted communication campaign<br>Fundings, subsidies, credits.<br>Rewards, incentives, encouragement, support. | Skeptics<br>Undecided | Apprehensive |
| **Low intentions** | Exposure to social norms.<br>Enhanced self-efficacy.<br>Self-–observation.<br>Exposure to desired behaviours.<br>Implementation intentions. | Interaction with EV owners.<br>Experiencing EV driving, test drives.<br>Learning from current EV owners.<br>Feedback and nudging. | Skeptic<br>Undecided<br>Potential adopter | Apprehensive<br>Unsure |
| **Negative values** | Improved connectedness to nature.<br>Transformational leadership.<br>Leadership expectations.<br>Enhanced pro-environmental commitment.<br>Cognitive reappraisal (i.e., Self-observation).<br>Social interaction. | Awareness of environmental benefits of EVs.<br>Leaders showing vision with EVs as a desirable value.<br>Information and awareness on impacts to environment.<br>Workshops / seminars.<br>Community initiatives/ | Skeptic<br>Undecided | Apprehensive<br>Unsure |
| **Hassle factor** | Provision of enabling factors.<br>Knowledge, information, awareness.<br>Exposure. | Facilitating i.e. home charging.<br>Awareness on technology and maintenance.<br>Simplification of information<br>Personalized assistance.<br>Learning from current owners. | Skeptic | Apprehensive |

**Note:** *Refer to text below for description of terms.

### 4.5.1 Strategies to change negative attitudes

To effectively change negative attitudes, it is crucial to understand that communication plays a pivotal role. Research suggests that employing **positive communication strategies** can be highly effective in promoting behaviour change. Positive communication involves framing messages in a way that emphasizes benefits, solutions, and encouragement. For instance, instead of focusing on the drawbacks of a certain behaviour, one might highlight the positive outcomes of adopting a new behaviour. Conversely, negative communication, which highlights faults, shortcomings, or negative consequences, often elicits hostile or defensive reactions from the audience. When people feel attacked or criticized, they are less likely to be receptive to the message and may even become more entrenched in their negative attitudes (N. C. Overall et al., 2009). For example, a study by Yoo, (2009) demonstrated that negative information about a health risk, when presented in a fear-inducing manner, can lead to increased anxiety and resistance to the message. This suggests that while negative content can grab attention, it may not always be effective in fostering long-term positive behaviour changes and can sometimes backfire by creating defensive reactions in the audience.

Research by (Jayamaha & Overall, 2015) further supports this idea, suggesting that negative and direct regulation strategies, such as imposing penalties, fines, and direct control measures (like revoking licenses for non-compliance with regulations), may not always effectively change attitudes. These punitive measures could face resistance from the targeted individuals or groups. Therefore, while negative regulation strategies can serve as deterrents, they may not always succeed in changing attitudes positively due to the potential for resistance and backlash.

In contrast, the use of **positive regulation strategies**, such as encouragement, rewards, and positive reinforcement, has been consistently linked to achieving desired behaviours and enhancing self-regulation efforts, which in simple terms, it is how a person manages to stay focused, motivated, and on track, even when faced with challenges or temptations (N. Overall & Fletcher, 2010). For example, Germany's Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act) implemented feed-in tariffs, offering long-term guaranteed payments to individuals and businesses that generated renewable energy. This financial reward acted as positive reinforcement, encouraging widespread adoption of solar and wind energy. As a result, Germany leads renewable energy production by motivating sustained investment in clean technologies (Huenteler et al., 2016).

Studies have explored how exposure to different types of content containing positive information can influence attitude change. This information can be provided in various mediums, such as videos, brochures, and personalized feedback. In a study conducted by Totsika & Jones, (2017), attitudes towards people with disabilities were significantly improved through the use of educational videos and brochures that highlighted positive stories and achievements of individuals with disabilities. This approach helped to foster empathy and understanding among the participants, leading to more favourable attitudes.

Previous studies have also identified effective strategies for changing negative attitudes, such as those towards electric vehicles, in particular in California.

**Motivation** plays a crucial role in changing negative attitudes, especially in educational settings. When students are motivated, they are more likely to engage with the material, participate in class, and adopt a positive attitude towards learning. Various motivational approaches and strategies in teaching have been identified as key factors in transforming negative attitudes into positive ones (Kralova, 2018)

One effective approach is to use **problem-solving instructional strategies**. These strategies focus on engaging people in activities that require them to think critically and solve problems, which can help to address and change poor attitudes. For example, if a group of people struggles with a specific goal, such as recycling, and develops a negative attitude towards the subject due to repeated failures, a campaign might implement problem-solving activities that break down the goal into smaller, manageable steps. This method can help the people experience small successes, gradually building their confidence and shifting their attitude from negative to positive (Fatoke & Olaoluwa, 2014).

**Box 5 EV Attitudinal Shift in California**

In California, a combination of policies successfully shifted negative attitudes toward electric vehicles and enabled positive tipping points in the EV market. Policymakers strategically mixed demand-side incentives, i.e. carpooling lane access for low-emission vehicles, with supply-side measures like subsidies for EV development, such as those supporting Tesla's innovations. These policy mixes not only reduced EV costs but also accelerated investments in EV technology and infrastructure. As a result, the market saw a rapid increase in EV sales and broader commitments to phasing out gasoline-powered vehicles by 2035. This shift shows how policy feedback—the interaction between technological and behavioral changes induced by policy—can reshape public opinion and interest group dynamics. As EV prices dropped and public infrastructure expanded, these technological changes fostered a political environment supportive of more stringent climate policies. The positive feedback loop between policy-driven technological advancements and changing societal behaviors and norms played a crucial role in achieving systemic change in California's transport sector. Source Fesenfeld et al., 2022.

### 4.5.2 Strategies to change low intentions

When aiming to shift low intentions towards a particular behaviour, it's essential to explore diverse strategies backed by research findings. One effective approach involves leveraging **social norms**, which represent the unwritten rules or standards that society deems as normal or acceptable behaviour. By using the power of social norms, it becomes possible to encourage and promote sustainable behaviours even among individuals with initially low intentions (Silberer et al., 2020). For instance, a campaign aimed at reducing plastic waste in a community: if the campaign highlights an exemplary behaviour, such as the widespread adoption of reusable bags and containers among neighbours, the campaign taps into the prevailing social norm of eco-consciousness, increasing the intentions of individuals to adopt similar practices despite their initial low intentions. This method can serve as a foundation for designing targeted strategies early in the development of sustainability measures, however, it has also been suggested that promoting social norms has a valuable role in improving pro-environmental actions, but these strategies are most likely to be effective where individual actions are immediately noticeable by the person and have an obvious and local effect. For example, having noticeable, live energy expenditure feedback when a specific action is performed (Perry et al., 2021).

Understanding the **intention-behaviour gap**, which is why people don't always act on their intentions, is essential for designing effective interventions in various areas like public health and energy conservation. One approach to address this intention-behaviour gap is with **implementation intentions.**

Implementation intentions are mental plans with target that a person has, that link specific cues to behavioural responses. These plans essentially map out a clear course of action for individuals. For example, someone might say, "If I feel warm (cue), then I will lower (behavioural response) the thermostat by one degree to save energy (target)". By having these plans in place, individuals are better equipped to follow through on their intentions. This strategy has been shown to be effective in bridging the divide between what people intend to do and what they actually do (Sheeran & Webb, 2016; St Quinton, 2022). An example of this is Ecosia, a search engine, plants trees with its ad revenue. It commits to: "If there is an online search, there will be trees planted." This aligns with the concept of implementation intentions, where a specific action (using Ecosia for searches) is tied to a specific situation (needing to search the internet), leading to environmental benefits (planting trees).

Additionally, **self-efficacy feelings**, which is an individual's belief in their own ability to successfully accomplish a task, achieve a goal, or overcome challenges, or in other words, their confidence, are important. When it comes to implementation intentions, low self-efficacy can get in the way, making people less likely to start new behaviours and sticking with them (Wieber et al., 2010). Self-efficacy feelings are enhanced by **self-observation** and exposure to the desired behaviour, therefore, effective ways of boosting an individual's self-efficacy, are watching oneself do the thing they want to do and seeing others do it too. An example of a campaign that demonstrates how self-observation can lead to changes in environmental behaviours is the "Become Part of the Solution" campaign. This campaign raises awareness about climate change by highlighting its impact on polar bears' extinction and promotes energy efficiency actions as a solution. It employs self-observation of behavioural effects of various factors, such as cost-saving benefits, environmental concerns, and social responsibility. For instance, homeowners are provided with energy-saving tips along with projected cost savings, directly linking energy efficiency to environmental conservation and social responsibility. Thus, individuals witness the positive effects of their actions on the environment, which lets them understand the benefits of their behavioural changes (IEA, 2022). Another example allowing self-observation, in this case for the acquisition of heat pumps is Pumpchic (Pumpchic, 2022). Pumpchic offers users a platform to observe their behaviour and build confidence in making decisions about heat pumps. Through the platform, users can track their behaviour and see the ways in which they are interested in heat pumps, thus allowing them to understand their own engagement with the information. Additionally, the platform's Augmented Reality feature lets users see what a heat pump installation could look like in their homes, further boosting and enhancing self-efficacy, thus, further boosting their confidence in their decision.

### 4.5.3 Strategies to change negative values

**Enhancing people's connectedness to nature** has emerged as a crucial factor in promoting environmentally friendly behaviour (Geng et al., 2015). Research conducted by Geng and colleagues in 2015 demonstrated that when individuals feel more connected to nature, they are more likely to engage in behaviours that benefit the environment. This connection to nature can manifest in various ways, such as appreciating natural landscapes, enjoying outdoor activities, or feeling a sense of responsibility towards the environment.

Furthermore, individuals' overall environmental attitudes and values play a significant role in shaping their behaviour towards the environment. Balundė and Perlaviciute (2019) highlighted the importance of factors like biospheric values and environmental self-identity in driving pro-environmental actions. Biospheric values refer to individuals' intrinsic motivation to protect nature and biodiversity, while environmental self-identity reflects how people perceive themselves in relation to the environment (Balundė et al., 2019).

For example, someone who strongly identifies as an environmentalist and holds deep biospheric values may be more inclined to recycle, reduce their energy consumption, or support conservation initiatives. Interventions aimed at promoting pro-environmental behaviour often target these underlying environmental considerations to foster a stronger connection to nature and a greater sense of environmental responsibility. By addressing these factors, interventions can effectively encourage individuals to adopt behaviours that contribute to the preservation and sustainability of the natural world.

**Box 6 Nature Passport Program by Natural Park Services in the USA**

The "Nature Passport" program aims to enhance people's connection to nature and encourage environmentally responsible behaviour, among children and families. It provides participants with an app with activities and challenges designed to foster exploration, learning, and appreciation of the natural world. These activities include identifying local flora and fauna, learning about ecosystems and wildlife habitats, practicing Leave No Trace principles, and engaging in outdoor recreation such as hiking, birdwatching, and nature photography. Participants also complete activities and earning stamps or badges for their achievements and are incentivized to actively engage with nature and adopt behaviours that promote its preservation. For example, participants learn about the importance of reducing single-use plastics and minimizing waste while enjoying picnics or outdoor activities in national parks, and to encourage following plant-based diets as a strategy for environmental conservation. Source (*Nature Passport* -, 2024).

**Cognitive reappraisal techniques** such as self-observation and reinterpreting situations in different ways, can significantly increase the likelihood of engaging in pro-environmental behaviours (Panno et al., 2020).

These techniques involve consciously changing the way one thinks about a particular situation to alter its emotional impact. For example, instead of seeing recycling as a tedious task, one might reframe it as a meaningful contribution to preserving the environment for future generations. By looking at the situation from a different perspective, individuals can reduce negative emotions and enhance positive feelings, which can motivate them to act more sustainably.

**Positive emotions** and **self-transcendent** emotions also play a crucial role in encouraging pro-environmental behaviour. Positive emotions, such as happiness and contentment, can increase people's willingness to engage in activities that benefit the environment. For instance, someone who feels positive about new technologies might be more inclined to acquire energy efficient innovations, like electric vehicles or solar panels (Zelenski & Desrochers, 2021). Self-transcendent emotions, such as awe, gratitude, and compassion, make people feel connected to a greater cause beyond themselves. These emotions can inspire individuals to take actions that benefit the community and the planet. For example, feeling a sense of awe can play a significant role in making individuals feel more connected to nature, and thus, more likely to engage in eco-friendly behaviours. This increased connectedness can strengthen the sense of community as individuals work together towards shared environmental goals. In turn, feeling part of a community can inspire awe, encouraging others to join energy communities. This shows how the feeling of connectedness can explain why awe leads to more ecological behaviours (Schaffer et al., 2024).

Promoting **environmental commitment**, which refers to an individual's dedication and responsibility towards protecting and preserving the environment, is an important strategy for encouraging green behaviour. This commitment can be fostered through various means such as information dissemination, education, awareness campaigns, and green challenges (Iqbal et al., 2023).

**Information campaigns** provide essential knowledge about environmental issues and the benefits of making eco-friendly choices. For instance, educating consumers about the impact of pollutants can motivate them to reduce their usage and opt for sustainable alternatives. By highlighting the long-term environmental benefits and personal health advantages of using eco-friendly products, these campaigns can influence purchasing decisions. **Educational initiatives**, such as offering workshops on sustainable living, help build a foundation of environmental awareness. **Awareness campaigns** can also play a significant role in fostering environmental commitment. For example, the "Earth Hour" campaign, where individuals and businesses are encouraged to turn off non-essential lights for one hour, raises awareness about energy consumption and climate change (EarthHour, 2024). This global movement not only spreads knowledge but also encourages collective action towards a common environmental goal. **Green challenges**, such as "zero waste" or "plastic-free" months, engage people in practical activities that demonstrate how small changes can lead to significant environmental benefits (EcoChallenge.org).

**Transformational leadership** involves inspiring individuals to adopt pro-environmental behaviours by acting as role models and communicating a clear vision for sustainability. These leaders foster a sense of shared purpose and environmental responsibility, motivating others to follow their example. **Leadership expectations** further reinforce this by setting norms and goals for sustainable practices, creating a culture where pro-environmental behaviour is encouraged and expected (Robertson & Barling, 2013).

**Box 7 Buy Nothing New Month in Australia**

*Buy Nothing New Month*, launched in Australia in 2011, encourages individuals to abstain from purchasing new items throughout October, promoting borrowing, swapping, or buying second-hand instead. The campaign has garnered significant participation, spreading to countries like the United States and the Netherlands. Thousands join annually, often through social media and community networks. Environmental impacts are substantial; if 10,000 people participate, with each person saving just 10 kg of waste, the campaign could prevent 100 tonnes of waste from reaching landfills in a single month. Financially, participants save considerable amounts, collectively amounting to millions of dollars, by avoiding new purchases. Surveys reveal lasting behavioural changes, with many continuing to prefer second-hand items post-campaign, highlighting the initiative's long-term influence on consumer habits. Media coverage from outlets, along with reports from environmental organizations such as Planet Ark, underscore the campaign's success and its contributions to sustainability by fostering a circular economy and reducing consumption. Source: (EcoChallenge.org).

**Social interaction** plays a crucial role in shaping individuals' environmental protection strategies and adjusting behaviours based on the environmental knowledge acquired through these interactions. When people engage in conversations and activities with others who prioritize environmental sustainability, they are more likely to adopt similar attitudes and behaviours. This is how social norms also ultimately are shared and adopted (X. Li et al., 2021). For example, community groups that organize events provide opportunities for members to learn about the specific practices conducted in the events (Marsden, 2008). These social settings facilitate the exchange of ideas and experiences, reinforcing positive environmental behaviours. Seeing peers commit to sustainable practices can motivate individuals to take similar actions, fostering a collective effort toward environmental protection.

### 4.5.4 Strategies to reduce the hassle factor

The **hassle factor** represents the perceived inconvenience individuals experience throughout various decision-making stages, often leading to stress and ultimately, inaction. This psychological barrier is prevalent not only in energy conservation behaviours but also in other pro-environmental actions. To effectively tackle this obstacle, de Vries et al. (2020), proposes a multifaceted approach to policy interventions. This includes initiatives such as **providing easily understandable** and credible information about green home measures, **emphasizing impactful actions**, and strategically **reinforcing messages** through diverse channels. Additionally, interventions like pre-selecting reliable contractors, offering **personalized assistance** during installations to minimize household disruption, and conducting behavioural trials (i.e. trying out the new behaviour to have exposure to it) can help alleviate the perceived hassle. Furthermore, simplifying subsidy or loan application processes, introducing prefilled forms, and implementing default policies favouring green options serve to streamline the greening process for homeowners, enhancing accessibility and reducing burdens. For example, the website service called ‘Get a Heat Pump’, provided by Nesta in the UK, aims to simplify the process of finding and installing air source heat pumps for homeowners (nesta, 2024). It provides clear, concise, and reliable information to help users determine if a heat pump is suitable for their homes, reducing the hassle factor associated with exploring green home technologies. Additionally, the platform offers guidance on the installation process, outlining each step from contacting installers to post-installation handover. It clarifies the installation procedure, so the service alleviates the perceived hassle of finding an installer and overseeing the installation process, ultimately facilitating informed decision-making, and encouraging the adoption of environmentally friendly practices. Similarly, in their technical report on behavioural change, the EEA highlights the importance of personalized approaches to energy efficiency measures and consumer engagement. It proposes that targeting specific consumer profiles, could enhance initiatives or platforms like the one-stop-shop by making the renovation process smoother and more tailored to individual needs. Customizing services according to behavioural profiles would likely reduce perceived hassle and increase adoption rates, similar to the general strategies discussed for changing consumer behaviour towards energy use (EEA, 2013). Finally, **exposure** involves giving individuals direct experience with new behaviours or technologies, helping reduce unfamiliarity and increase adoption. For instance, test drives for electric vehicles or demo projects for solar panels can make people more comfortable and likely to engage in pro-environmental actions. Research shows that direct exposure significantly increases the adoption of green technologies by reducing perceived risks (Herziger & Sintov, 2023).

# 5 Conclusions

## 5.1 Historical overview on EU EDM

The European Union stands at a critical juncture in its energy strategy, advancing a dual approach that combines demand management with renewable energy investment. This strategy simultaneously reduces energy use and increases sustainable supply, aiming for the EU's 2050 climate-neutrality goals. Energy Demand Management (EDM) has already proven effective in reducing emissions, improving energy security, and lowering costs—making it indispensable for building a sustainable European energy landscape.

Historically, energy crises like those in the 1960s and 1970s spurred Europe to prioritize energy security, leading to today's EU-wide framework for EDM. The Energy Services Directive (2006) and Energy Efficiency Directive (2012) established shared efficiency targets and mandated National Energy Efficiency Action Plans (NEEAPs), marking a major shift from fragmented national policies to a coordinated EU effort. Without these initiatives, research indicates that energy consumption across the EU27 plus Norway would have been about 12% higher by 2013. Yet, significant challenges remain, particularly the need for behavioural shifts, cultural acceptance of energy-saving technologies, and sustained investment.

To address these issues, EDM policies should incentivize energy-saving behaviours through price signals and incorporate price elasticity insights. Enhancing energy literacy and ensuring fair policy implementation are equally essential to prevent a disproportionate burden on low-income households. Continuous monitoring and evaluation are also vital, capturing both direct and indirect effects of EDM policies to adjust and enhance their impact.

## 5.2 Approaches for monitoring and evaluation of policy related to EDM

Transition costs for households, such as home renovations or electric vehicle purchases, can represent up to 1.4 years of average household income, which underscores the need for public support and fair cost distribution to achieve political and social acceptance. Effective monitoring and evaluation mechanisms are essential but often fail to capture the full dynamics of EDM policy impacts. Simplified expert models that simulate policy impacts could provide policymakers with practical insights, bridging the gap between complex analysis and actionable decision-making.

Given the complexity of energy systems, minor adjustments may yield limited results, highlighting the value of user-friendly simulation tools for policymakers. Key success factors include strong monitoring to reduce overlapping policy effects and targeted energy literacy efforts to counteract behavioural challenges like rebound effects. Such tailored approaches ensure that policies serve specific groups effectively, making them more adaptable and relevant.

## 5.3 User-centred policy design

Integrating social sciences into energy policy is essential for understanding and encouraging public adoption of energy-saving technologies. Research shows that psychological and behavioural factors, such as pro-environmental values and emotional engagement, often drive energy-saving behaviours more effectively than demographic factors.

Consumer segmentation based on attitudes and behaviours can guide tailored strategies to increase acceptance of sustainable practices. For example, segmentation in Portugal and Norway identified profiles like EV Advocates, Sceptics, and Enthusiasts. Strategies that emphasize positive messaging, reduce perceived barriers, and engage community leaders effectively address behavioural determinants, helping bridge the gap between intent and action.

Tailoring interventions to specific profiles can enhance policy outcomes across different social and cultural contexts. Through these approaches, EDM can more effectively support the EU's climate goals while fostering broad public buy-in for a sustainable energy transition.

This evolving approach demonstrates the EU's commitment to a sustainable, low-carbon future. As energy systems and consumer attitudes continue to change, ongoing adaptation of EDM strategies—anchored in public behaviour and real-world impacts—will be crucial. Such a responsive and people-centred approach can position the EU as a leader in achieving climate neutrality by 2050.

## 5.4 Limitations and future topics

Despite the progress in EDM policies, challenges persist in accurately capturing the behavioural and systemic impacts of these initiatives. Current monitoring and evaluation mechanisms often overlook indirect effects, such as rebound behaviours or social inequalities in policy outcomes. Additionally, the scalability of tailored interventions and their effectiveness across diverse cultural and socioeconomic contexts remain underexplored. Limited data availability and reliance on simplified models may further constrain policymaking.

**Future Topics:**

- Developing advanced simulation tools that integrate behavioural and systemic dynamics for more precise policy design.
- Investigating the long-term social equity impacts of EDM policies to ensure just transitions.
- Exploring the role of digitalization and smart technologies in enhancing EDM strategies.
- Conducting cross-cultural studies on energy-saving behaviours to refine segmentation and tailoring methods.
- Assessing the potential of emerging concepts like sufficiency and energy citizenship in driving systemic change.

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# Annex A

## . Fuzzy cognitive map modelling

To process the data we Once the data gathered, fuzzy logic was subsequently applied to convert the linguistic ratings into numerical weights using the partial memberships functions (i.e. various degrees of memberships in a set or fuzzy set) described in Mkhitaryan et al., 2022 (Mkhitaryan et al., 2022). The fuzzy set of values can be defined as a set of ordered pair values and is mathematically represented as:

$$A = \{(x, \mu_A(x) | x \in U)\}$$

where,

- A represents the fuzzy set.
- x represents an element in the universe of discourse U.
- $\mu_A(x)$ represents the degree of membership of element x in set A.

To convert the linguistic ratings into numerical weights, we employed the FCMpy python module developed by Mkhitaryan et al., 2022 using a triangular membership curve. Next, the resulting membership functions where combined both at the energy agency level (if there were more than two experts maps) and across all energy agencies through aggregation operation ([10]) (Mkhitaryan et al., 2022). To determine the most likely cluster for a data point during the aggregation process of FCMs, we used the family maximum aggregation operation.

$$Max_{Family}\{A^1, A^2, A_n\} = \max\{\, a \in U \mid a \in A_i \; for\ some\ i \in \{1,2, \ldots, n\}\}$$

where,

- $Max_{Family}$: This represents the family maximum operation.
- $A_1, A_2, \ldots, A_n$: These represent the individual sets in the family (can be any number of sets).
- max: This represents the maximum function.
- a: This represents an element within the universe of discourse (set of all possible elements).
- *U*: This represents the universe of discourse.
- $\{i \in \{1, 2, \ldots, n\}\}$: This part specifies that element a must belong to at least one of the sets in the family ($A_1, A_2, \ldots, A_n$).

[10]) To allow aggregation of the maps when only a single expert provided input, we duplicated the input. This was done for all countries except Germany, where two experts participated. Although not ideal, this manipulation serves as a shortcut to ensure sufficient data for analysis.

The final step involves defuzzification using the centroid method to convert fuzzy memberships into crisp values for each data point (Mkhitaryan et al., 2022). This is done by taking the membership degree in the cluster, denoted as $\mu_c(x_i)$. Then, the "centre of gravity" or centroid in the cluster is calculated using a weighted sum. Here, the weight for each data point is its corresponding membership degree ($\mu_c(x_i)$) in the current cluster. Data points with higher membership (stronger association with the cluster) contribute more to the weighted sum, ultimately influencing the location of the centroid.

$$centroid_c = \frac{\Sigma\,(\mu_c(x_i) * x_i)}{\Sigma\,(\mu_c(x_i))}$$

where,

- Centroid c: represents the centroid (crisp value) for the current cluster c.
- $\mu_c$: denotes the membership degree for the current cluster (c).
- $x_i$: this represents the i-th data point in the dataset.
- $\mu_c(x_i)$: represents the membership degree of data point x_i in cluster c

### *System centrality*

Centrality measures in the context of Fuzzy Cognitive Maps (FCMs) help identify influential concepts or variables within the network. Centrality measures analyse the connections (edges) in the weight matrix. In this study we are using the common degree centrality equation described in the "*networkx*" python package.

a) Degree centrality (overall connection count) is based on the assumption that the important nodes have more connections and calculates the total number of connections (incoming and outgoing edges) a concept has. A concept with a high degree centrality is highly connected and potentially plays a significant role in information flow within the FCM. The formula is as follows: $centrality_{degree}(v) = \frac{d_v}{(|N|-1)}$

where,

- dv: is the degree of node v
- N: total number of nodes in the network

b) Closeness centrality considers how quickly information can be spread from a concept to all others. A concept with high closeness centrality is "closer" (on average) to all other concepts, suggesting it might be a good central point for information dissemination. Closeness Centrality is calculated by summing the **shortest path lengths** from the given concept (node) to all other concepts in the network. A shorter path length indicates a more direct connection and potentially faster information flow. The formula is as follows:

$$centrality_{closeness}(v) = \frac{(|N| - 1)}{\Sigma d(v,j)} \text{ for all j } \neq \text{ v}$$

where,

- |N|: Total number of nodes in the network
- j: represents all other nodes in the network except for node v (j ≠ v)
- d(v,j): shortest path length between node v and node j

However, in some networks, certain concepts might not be connected to all others. For these cases, Closeness Centrality is calculated using a variant of closeness centrality specifically designed for disconnected networks. It incorporates the concept of reachable nodes (`R(v)`) to account for situations where not all nodes are connected. The formula to calculate Closeness centrality is the following:

$$centrality_{closeness}(v) = \frac{|R(v)|}{|N-1|} * \frac{|R(v)|}{\Sigma_{(\mathrm{u}\in\mathrm{R(v)})} d(v,j)}$$

where,

- |N|: Total number of nodes in the network
- |R(v)|: Number of nodes reachable from node v (excluding itself).
- d(v,j): shortest path length between node v and node j
- Σ_(u∈R(v)): Summation over all nodes j reachable from node v.

c) Betweenness centrality is a measure of a node's importance in a graph based on the number of shortest paths that pass through the node. It assumes that important nodes connect other nodes by lying on the paths that link them. The formula for calculating Betweenness centrality is as follows:

$$centrality_{betweeness}(v) = \sum \text{s,t∈Nσs,tσs,t(v)}$$

where,

- |N|: Total number of nodes in the network

- $\sigma_{s,t}$: is the number of shortest paths between nodes s and t
- $\sigma_{s,t}(v)$ is the number of shortest paths between nodes s and t that pass through node v.

***Graph similarity***

To assess the similarity between graphs, we used the Eigenvalue graph similarity index that compares two FCM using their adjacency matrices. It leverages the Laplacian matrices of the graphs and considers the top k significant eigenvalues to determine the similarity. This is done in three steps:

Given two adjacency matrices $A_g$ (for group g) and $A_{exp}$ (for experts), we can compute the eigenvalue graph similarity index as follows:

**Calculate the Laplacian matrix:**

$$L = \text{D-A}$$

where;

- D is the degree matrix (a diagonal matrix where each diagonal element Di is the degree of node i)
- A is the adjacency matrix.

**Calculate significant eigenvalues: finding the smallest k such that the sum of the top k eigenvalues is at least $k_{threshold}$ (typically 0.9) of the total sum of eigenvalues:**

$$k = min(k_{g,} k_{exp})$$

where;

- $k_g$ and $k_{exp}$ are the smallest k for the group and expert Laplacian matrices, respectively.

**Compute the similarity index: calculating the squared differences between the top k eigenvalues of the Laplacian matrices:**

- $$Similarity\ index = \sum_{i=1}^{k}\left(\lambda_i^g - \lambda_i^{exp}\right)^2$$

where;

- $\lambda_i^g$ and $\lambda_i^{exp}$ are the top k eigenvalues of the Laplacian matrices for the group and expert FCMs, respectively.

The Eigenvalue graph similarity Index is the sum of the squared differences between the top k eigenvalues, with a lower value indicating greater similarity between the two FCMs in terms of their underlying eigenvalue structure.

***Simulation of system behaviour for scenario analysis***

To generate educated estimates based on common practices and trends observed in European energy policies, we use the AI tool Gemini. The following question was asked:

> *"Can you provide an estimate in percentage for any of these values according to your knowledge about how much they are often implemented in European countries to promote energy demand reduction policies? For example, you could indicate that ease of implementation is an overall well-addressed factor (75%) or that the unequal impact on vulnerable consumers is rarely considered (10%), etc. Do this for each of the provided factors are as follows: [list of factors]".*

Gemini responded by generating a list of estimated implementation levels along with rationales for each factor:

Factors with likely High implementation (60-80%)

- F3: Continuous financial support available (70%): Similar to the previous list, the EU and many member states offer financial support mechanisms for clean energy projects.
- F9: Favourable regulatory frameworks (65%): The EU has established a comprehensive legal framework for energy efficiency and renewable energy, with some variation in implementation across member states.
- F22: Support from industry and stakeholders (60%): Decarbonization goals are prevalent in many European industries, and stakeholder engagement is recognized as crucial.

Factors with Moderate implementation (50-59%)

- F4: Ease of implementation (55%): The EU strives for user-friendliness, but administrative burdens can still exist for EDR implementation.
- F11: Good alignment with public opinion values (50%): Public support for clean energy initiatives is generally high in the EU, but specific EDR policies might not always perfectly align with public opinion.
- F12: Good transparency and trustworthiness (50%): Transparency is a core EU value but achieving it fully across all member states can be challenging.

Factors with Varied implementation (20-49%)

- F1: Adequate information and expertise (45%): Availability varies across member states, with some having dedicated agencies but others potentially lacking resources.
- F5: Existence of local expertise network favouring implementation (40%): The presence of local expertise networks can vary depending on the specific region and technology involved in data reporting.
- F10: Flexibility to adopt changes or include modifications (40%): While some flexibility exists in EU policy, national implementation might vary regarding EDR adaptations.

- F18: Poor consumer engagement (40%): While initiatives exist, more needs to be done to improve consumer awareness and participation in EDR programs.
- F20: Stable long-term policy with a clear mandate (40%): Without details on the specific EDR policy design and its commitment to long-term stability, a conservative estimate would be 40%. This acknowledges the importance of long-term policy but reflects the uncertainty about the specific EDR program.
- F2: Available technology or innovation levels (35%): Technology access and innovation capabilities differ greatly, impacting policy implementation across countries. This can be particularly relevant for data collection and reporting methods.
- F23: Unequal impact on vulnerable groups (20%): While recognized as an issue, specific policy measures are still evolving, leading to a lower score.

Factors with Lower implementation (5-19%)

- F6: Existence of negative behavioural effects (15%): The specific design of EDR policies can influence behaviour, but the overall impact is likely to be evaluated after implementation.
- F16: Lack of skilled workforce (15%): The specific skills needed for EDR might not be in short supply across all member states.
- F13: Governance structure and leadership clarity (15%): The EU provides a governance framework, but national implementation structures might vary in clarity.
- F7: Existence of other overlapping or opposed policies (10%): Overlapping policies are less likely for a specific area like EDR, but some national regulations might need adjustments for better alignment.
- F8: Existence of split-incentive issues (10%): Split-incentive issues (e.g., landlord-tenant) might be less prominent for data reporting compared to other policy areas.
- F15: Lack of monitoring (10%): Monitoring and evaluation are crucial for policy effectiveness, but establishing robust monitoring systems can take time.
- F17: Low energy prices (10%): While energy prices can influence reporting behaviour, this factor might be less relevant for the design of the EDR policy itself.
- F19: Proven cost-effectiveness (10%): Cost-effectiveness is often evaluated after policy implementation, and specific data for EDR programs might be limited.
- F14: Inappropriate group targeting (5%): EDR policies are likely designed to be broadly applicable, minimizing the risk of inappropriate targeting.

Target factor F21: "*Successful energy demand reduction policy in your country*" was given a conservative estimate of 50%. On these bases, we use the *FcmSimulator* module from the FCMpy package (Mkhitaryan et al., 2022) to find the system's equilibrium prior to the scenario testing. A maximum of 50 iterations were allow for the system to find an equilibrium. To update the concept values over each discrete simulation steps, we employed the modified Kosko inference method: $A_i^{(t+1)} = f\left(A_i^{(t)} + \sum_{j=1}^{n} A_j^{(t)} * w_{ji}\right)$

where,

- $A_j^{(t)}$: is the concept j at the simulation step t

- $w_{ji}$ is
- the causal impact of concept j on concept i

A sigmoid transfer function was applied to the result to keep values within the [0,1] range. $f(x) = \frac{1}{1 + e^{\lambda x}}, x \epsilon \mathbb{R}$

where,

- $x$::: is the value calculated by applying the Kosko inference method
- $\lambda$: is steepness parameter for the sigmoid function

### *Parameters Hierarchical clustering*

The cluster methodology employed in this research involves hierarchical clustering of countries based on pairwise comparisons of eigenvalue indices derived from fuzzy cognitive map (FCM) analyses. First, the comparison data for each country pair is extracted and organized into a comparison matrix where each entry represents the strength of influence or similarity between two countries. Hierarchical clustering is then performed on this matrix using the average linkage method. The resulting linkage matrix (Z) is used to construct a dendrogram, visually depicting the hierarchical relationships among countries. The dendrogram plot provides insights into how countries group together based on their comparative similarities or influences, facilitating the identification of clusters or groups within the dataset.

### *Scenarios definition*

**Scenario 1:** Increased involvement from market actors: this scenario explores the potential impact of stronger engagement and support from market actors in energy demand reduction initiatives prompted by allocated R&D investment funds. The core assumption is that market actors will be participate strongly and promote these initiatives. Based on these premises, the model is adjusted as follows:

| | Single-shoot Intervention | Weight | Factor's influence |
|---|---|---|---|
| Scenario 1 | Values were added as: | | |
| | Increased investment in energy and policy R&D for industry and stakeholders' participation | → (80%) | Support from industry and stakeholders |
| | | → (20%) | Continuous financial support available |
| | | → (80%) | Adequate information and expertise |
| | | → (80%) | Available technology or innovation levels |

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**Scenario 2:** Worsen situation: this scenario explores the impact of weaker conditions at the policymaking level on monitoring and evaluation processes. It simulates negative impacts on policy control, monitoring and implementation mechanisms within the system. Subsequently, the model undergoes the following updates:

| | Single-shoot Intervention | Weight | Factor's changes |
|---|---|---|---|
| Scenario 2 | **Baseline values were changed for:** | | |
| | Worsen situation | → (-80%) | Ease of implementation |
| | | → (-60%) | Flexibility to adopt changes or include modifications |
| | | → (60%) | Lack of monitoring |
| | | → (80%) | Existence of other overlapping or opposed policies |

**Scenario 3:** Emphasizing user-centricity and customization: under the assumption that targeted information tailored to citizens' profiles is readily accessible. This scenario captures the availability of tailored policies and information regarding the benefits of adopting energy demand reduction behaviours. The model then stays as follows:

| | Continuous Intervention | Weight | Factor's changes |
|---|---|---|---|
| Scenario 3 | **Baseline values were changed for:** | | |
| | User-centricity and customization to promote user engagement | → (-60%) | Poor consumer engagement |
| | | → (-60%) | Inappropriate group targeting |
| | | → (-25%) | Existence of negative behavioural effects |

**Scenario 4:** Focus on shortest paths (betweenness centrality): This scenario leverages betweenness centrality, a network analysis method used to identify key factors (nodes) that act as bridges within the system, facilitating the flow of influence or information. By targeting these critical nodes, we can enhance the effectiveness of interventions and accelerate the desired outcomes. In practical terms, factors identified as having high betweenness centrality are seen as pivotal in spreading the influence of key actions throughout the network. This scenario simulates a 25% increase in the strength of these key factors, optimizing their impact within the system. The updated values of these factors reflect the heightened role they play in ensuring smoother and more efficient pathways for the dissemination of information, influence, or support across the network. The values are then updated as follows:

| | Continuous Intervention | Weight | Factor's changes |
|---|---|---|---|
| | **Baseline values were changed for:** | | |
| Scenario 4 | Improved weight of central factors as assessed by betweenness centrality | → (81%) | Favourable regulatory frameworks |
| | | → (56%) | Adequate information and expertise |
| | | → (50%) | Poor consumer engagement |
| | | → (88%) | Continuous financial support available |
| | | → (44%) | Available technology or innovation levels |
| | | → (75%) | Support from industry and stakeholders |

### *Study limitations*

One limitation of this study worth mentioning is that during the interviews, the experts had differing focuses depending on their sector expertise. Although this variation was somewhat mitigated by the diversity of experts interviewed, some were more concerned with EDR in the context of industry, while others concentrated on buildings. In future studies, it might be beneficial to create separate models for each sector, allowing them to be interconnected across common factors that influence the final outcomes. This approach would involve first defining the sectors and then conducting parallel testing, where experts would focus on the respective sectors separately.