Document D4.3
Date Nov 2024

D4.3
Policy impact analysis

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This project has been funded by the European Climate Infrastructure and Environment Executive Agency under the LIFE call, LIFE-2021-CET-POLICY, with grant agreement N° 101076631.

Revision History

Version	Authors	Description	Checked by	Date
v.0	Robin Barkhausen (ISI) Antoine Durand (ISI)	Draft for 17/18.09.2024 project meeting	-	17.09.2024
v.1	Robin Barkhausen (ISI) Antoine Durand (ISI) Nikos Ntaras (CRES) Wolfgang Eichhammer (IEECP)	Draft for review	Konstantin Kulterer (AEA) Christian Praher (AEA)	18.11.2024
v.2	Robin Barkhausen (ISI) Antoine Durand (ISI) Nikos Ntaras (CRES) Wolfgang Eichhammer (IEECP)	Final version	-	28.11.2024

List of Acronyms

AEA	Austrian Energy Agency
CO_{2eq}	Carbon Dioxide Equivalent
EEN	Energy Efficiency Networks
EESL	India’s Energy Efficiency Services Limited
EIA	Energy-Investment Allowance
EnMS	Energy Management Systems
ETS	Emissions Trading System
EU-M^3	EU-MORE Motor Model
EZK	Dutch Ministry of Economic Affairs and Climate
GHG	Greenhouse Gases
ICA	International Copper Association
IoT	Internet of Things
IRR	Internal Rate of Return
LCA	Life Cycle Assessment
MEPS	Minimum Energy Performance Standards
MEErP	Methodology for Ecodesign of Energy-Related Products
MFA	Material Flow Analysis
NMRP	India’s National Motor Replacement Program
PMSM	Permanent Magnet Synchronous Motors
PPEC	Energy Efficiency Promotion Plan
RSE	Ministry of Climate and Business
RVO	Netherlands Enterprise Agency
SCIM	Squirrel Cage Induction Motors
SEA	Swedish Energy Agency
SFOE	Swiss Federal Office of Energy
SME	Small and Medium-Sized Enterprise
SynRM	Synchronous Reluctance Motors
VSD	Variable Speed Drive

EU-MORE is an acronym for
EUropean MOtor
REnovation initiative

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1. Executive summary

The EU-MORE project, in its Work Package 4 (WP4), aims to develop and implement tools for the projection, monitoring, and evaluation of motor replacements. The central pillar of these efforts is the developed **EU-MORE Motor Model (EU-M³)**, a comprehensive analytical tool designed to measure the impact of existing and emerging policies on the energy consumption and greenhouse gas emissions of electric motors.

The purpose of this report is to explain the development and functionality of the model, the process of policy selection and finally to provide examples of policy impact modelling.

The **EU-M³** is developed following a five-step methodology. The **first step** involves defining the delimitations and requirements of the model, identifying the specific motor systems and policies to be considered. The **second step** requires identifying and gathering the necessary inputs, which include data and assumptions to translate policies into model parameters. In the **third step**, a conceptual model is developed to serve as a framework for data analysis. The **fourth step** involves developing an approach for presenting the results for clarity and ease of interpretation. The **final step** is the technical implementation of the model in an appropriate software environment.

Based on the motor policy assessment conducted in previous working steps of the EU-MORE project (Faassen et al. 2024), financial and non-financial policies for motor replacement are selected for investigation: a subsidy scheme, a tax incentive, and information campaigns. These policies are translated into model input parameters to assess their impact on the EU level in the area of motor system improvements.

The model results suggest that the chosen motor policies can substantially decrease energy demand and greenhouse gas (GHG) emissions. However, the model does have limitations. The reliability of the results is contingent on the quality of user inputs, which can vary significantly. Additionally, several simplifications were necessary during the model's development and implementation, and these are further detailed in this report.

Overall, the **EU-M³** is an innovative tool that can provide valuable insights for policy makers and other stakeholders. It allows for a detailed understanding of the impact of motor replacement policies and can help developing effective strategies for improving energy efficiency in the European motor market.

The model itself was designed as D4.2 of the EU-MORE project and can be downloaded from the project website https://eu-more.eu/. By February 2025 the website will also include support documents for the stock model (as D4.5), including an interactive presentation and a tutorial video on how to use the model.

2. Background, aim and methodology

2.1 Background & aim

The Policy Impact Analysis (D4.3) is part of Task 4.2 of Work Package 4 (WP4) of the EU-MORE project. WP4 focuses on tools for projection, monitoring and evaluation of motor replacement. The aim is to analyse the impact of existing and new motor policies and identify the most promising levers in terms of energy consumption and greenhouse gas intensity. The aim is to enable stakeholders, in particular policy makers, to understand the impact of motor policy and to enable them to carry out their own analyses. WP4 also aims to develop methodologies for integrated data collection, verification, monitoring, evaluation and reporting on policy implementation, as well as simple and streamlined methods for calculating deemed savings to take into account the contribution made by motor renovation. Finally, knowledge on non-energy benefits should be provided.

Within WP4, Task 4.2 aims to provide the necessary tools to analyse the impact of existing and new policies on electric motors, using the data collected in WP1 and Task 4.1. The task will result in an impact and projection tool, based on a stock model, for scenario-based analyses of policy impacts on energy demand and greenhouse gas emissions. By reflecting the environmental impacts of motors, an understanding of the direct and indirect effects of energy-related policies on motors and the underlying efficiency measures can be provided.

Figure 1 provides an overview of the inputs and outputs of Task 4.2 and the interrelationship with other tasks in the EU-MORE project.

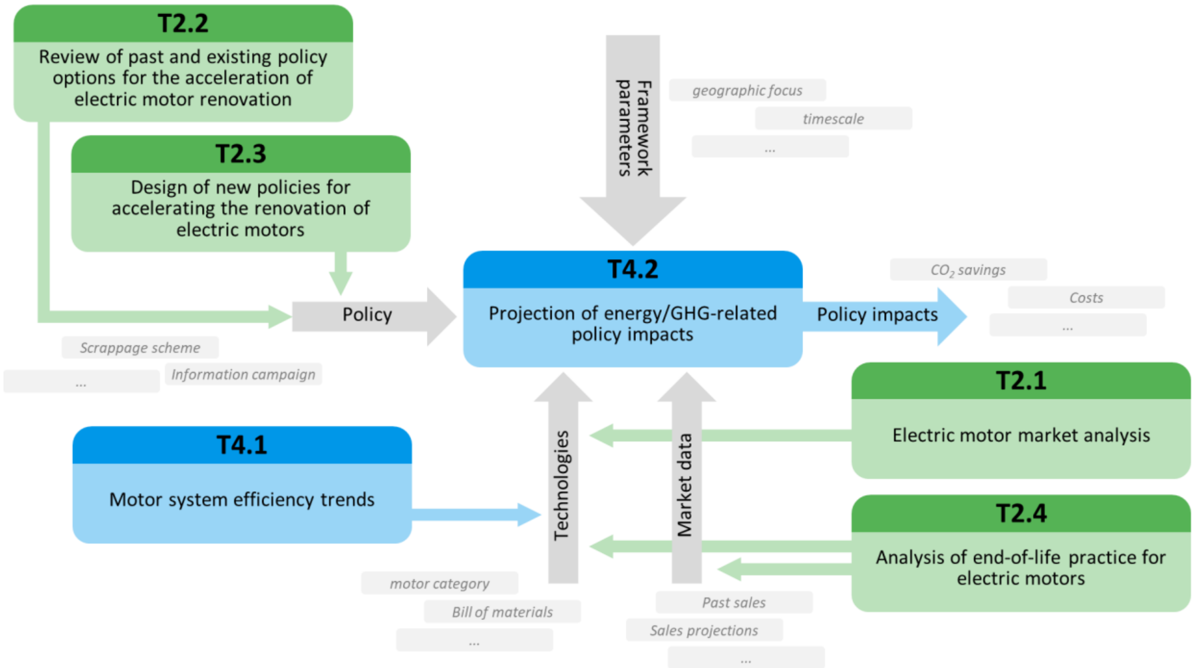

Figure 1 Overview of Task 4.2 inputs and outputs

Moving forward in this publication, the developed model will henceforth be referred to as the **EU-MORE Motor Model (EU-M³)** for ease of reference and consistency.

2.2 Methodology

The methodology deployed for the development of the **EU-M³** is following a five step approach (see Figure 2). The methodology is detailed in the following paragraphs and then further explained and applied in chapter 3.

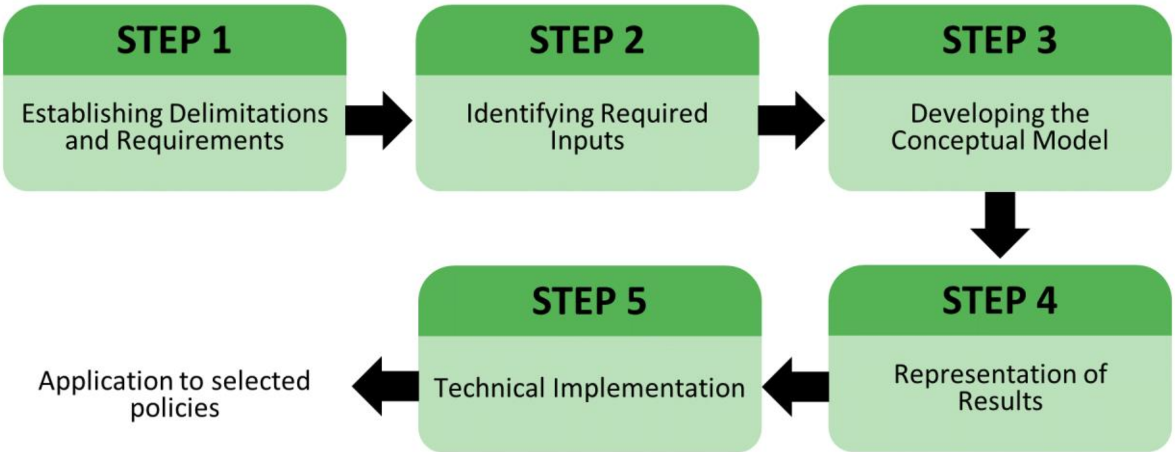

Figure 2 Methodology for developing the EU-M³

Step 1: Establishing Delimitations and Requirements

This initial step establishes the boundaries and requirements of the motor system stock model. It includes outlining the model's scope, identifying the specific motor systems and policies to be considered, and setting the limits of the model application.

Step 2: Identifying Required Inputs

This step involves the identification and collection of the required inputs. It involves gathering the necessary data and formulating assumptions to translate the policies into model parameters. Data sources are primarily based on the research carried out in WP2 (T2.1, T2.2, T2.3, T2.4) and WP4 (T4.1) supplemented where necessary by information needed as framework parameters found in industry reports, policy documents and other relevant publications.

Step 3: Developing the Conceptual Model

Once the necessary inputs have been compiled, the third step is to develop the conceptual model. This model will serve as the fundamental framework for analyzing the data and generating results. It is designed to process the inputs and translate them into quantifiable impacts on energy demand and GHG emissions.

Step 4: Representation of Results

In this step, an approach for presenting the results generated by the conceptual model is developed to ensure clarity and ease of interpretation. This approach may incorporate graphical visualizations, tables, and descriptive statistics.

Step 5: Technical Implementation

The final stage of the methodology is the technical implementation of the model on an appropriate platform. This involves coding the model, testing its functionality and troubleshooting any problems that may arise.

The presented process ensures the robustness and applicability of the model and provides meaningful insights into the impact of motor policies.

The model development according to the described methodology is presented in in chapter 3. Thereafter, the policy selection is presented in chapter 4, followed by a translation into model input parameters and assessment through the model in chapter 5, including presentation and discussion of the results. The report closes with a summary and conclusion in chapter 6.

3. Model

3.1 Delimitations and requirements

The **EU-M³** is meant to analyse the impact of existing and new policies on electric motors and enable stakeholders, in particular policy makers, to understand the impact of motor policy and to enable them to carry out their own analyses. Delimitations and requirements are mainly derived from the aim of this task (T4.2), as well as previous tasks within the EU-MORE project, namely the electric motor market analysis (T2.1), the assessment of end-of-life practices (T2.4) and motor system efficiency trends (T4.1), the review of past and existing policy options (T2.2) as well as the design of new policies (T2.3) (see Figure 1).

Any modelling activity can only be as accurate as the underlying data, so the inputs are extremely important and can to some degree determine the scope of the **EU-M³**. In the case of the European motor market, the last in-depth study was almost two decades ago, and a recent US Motor System Market Assessment has cast doubt on the reliability of typical assumptions about motor life, load factor and operating hours - all crucial for estimating electricity consumption (Fong and Almeida 2024). The comprehensive EU-MORE motor market analysis (D2.1) filled this gap by assessing the EU-27 electric motor market, providing data on motor sales by technology, power range and efficiency class. The report provided an estimate of the installed base of motors and their electricity consumption, but also highlighted the need for accurate and recent data on the characteristics of the installed base, as discrepancies were found between estimated and expected electricity consumption (Fong and Almeida 2024). Despite potential uncertainties in these figures, they are considered to be the best available representation of the European motor market and the **data will therefore serve as the basis for calculating the potential savings** linked to the policy recommendations proposed by EU-MORE.

Consequently, the **EU-M³** will be applicable to the EU-27 market for industrial electric motors. In addition, the European market figures can be scaled up to Member State level using a conversion factor based on gross electricity production as a rough proxy for industry size (Eurostat 2024a). For the sales values (including the shares of motor types, e.g. power range and efficiency class), datasets on the stock[1] are provided from the University of Coimbra from 1985 to 2036 as part of the analysis of the market (Fong and Almeida 2024). These values are linearly extrapolated to construct a scenario up to 2050 and sales are reversely calculated based on motor lifetime to match the stock.

On the individual motor level, the analysis of motor system efficiency trends (D4.1) covers the evolution of electric motor technology and the increasing emphasis on energy efficiency. It details various motor technologies such as induction motors, synchronous motors, permanent magnet motors, axial flux motors, line-start permanent magnet motors, and synchronous reluctance motors.

[1] In this analysis the term „stock“ refers to the cumulated number of electric motors sold and in use. The stock changes as motors are sold (or enter the market) and motors reach the end of their life (or leave the market).

It also discusses variable speed drives and their energy efficiency classes. The analysis highlights the role of digital technologies like Internet of Things (IoT) in monitoring and improving motor systems' performance. It presents the potential of real-time data, maintenance (condition-based and predictive), process optimization, and energy savings. It also addresses the challenges of implementing digital technologies in motor systems, like organizational barriers, lack of technical knowledge, capital costs, and cybersecurity concerns. The analysis finds that induction motors with IE4 efficiency are widely available, while technologies like permanent magnet motors and synchronous reluctance motors promise to exceed IE4 efficiency limits. Indeed, an observable shift is noted towards using permanent magnet synchronous motors (PMSM) and Synchronous Reluctance Motors (SynRM) in applications where speed variation is necessary. The preferred choice for fixed speed applications is still three-phase squirrel cage induction motors (SCIM) due to their reliability. The report highlights the potential of variable speed drives (VSDs) in improving the energy efficiency of motor systems, especially in systems where load variation is required (Fong et al. 2024).

For the development of the **EU-M³**, it is necessary to have clearly distinct motor types with their respective product characteristics such as power, operating time and efficiency. In this case, based on knowledge gathered in EU-MORE during the analysis of motor system efficiency types, the motor types are divided into six efficiency classes (IE0 to IE5) and five power ranges (0.75-7.5 kW to >375 kW). Efficiency classes IE0 to IE4 represent SCIM motors while IE5 motors represent SynRM motors. The use of VSDs is not included in the model due to a lack of reliable data on the effects.

3.2 Required inputs

Many of the required inputs have already been mentioned in the previous subchapter and are listed in a structured manner in Table 1 below. The required inputs can be categorized into those related to technologies, market data, framework parameters and policies (see Figure 1) and are primarily derived from research carried out in WP2 (T2.1, T2.2, T2.3, T2.4) and WP4 (T4.1) supplemented where necessary by information needed as framework parameters found in industry reports, policy documents and other relevant publications.

In addition to the above mentioned inputs, the user has to input information to assess the policy. Such information includes geographical scope (EU or Member State), motor power class, programme budget, funding rate per motor, timeframe of the policy, lifetime reduction, as well as impacted efficiency classes (of the motors to be replaced and the motors replaced with them). More information on the user inputs can be found in chapter Table 1.

Table 1 Data inputs with their respective data sources

		Source					
		T2.1	T2.2	T2.3	T2.4	T4.1	Other
Technologies (for each motor power range & efficiency class)	Power	X					University of Coimbra (Fong, João) (2024)
	Efficiency	X				X	University of Coimbra (Fong, João) (2024)
	Operating time	X					University of Coimbra (Fong, João) (2024)
	Load factor	X					University of Coimbra (Fong, João) (2024)
	Lifetime	X			X		University of Coimbra (Fong, João) (2024)
	Product price	X					University of Coimbra (Fong, João) (2024)
	Bill-of-material	X				X	University of Coimbra (Fong, João) (2024)
Market data	Sales	X					University of Coimbra (Fong, João) (2024)
	Stock	X					University of Coimbra (Fong, João) (2024)
	Share of efficiency classes	X					University of Coimbra (Fong, João) (2024)
	Share of power ranges	X					University of Coimbra (Fong, João) (2024)
Framework parameters	Electricity price[2]						Eurostat (2024b)
	Gross electricity production						Eurostat (2024a)
	Electricity mix emissions						European Commission (2014)
	Material environmental impacts						European Commission (2014)
Policies	Policy type		X	X			(Faassen et al. 2024)
	Cost effectiveness		X	X			(Faassen et al. 2024)
User inputs	Geographical scope						User input
	Motor power class						User input
	Programme budget						User input
	Funding rate per motor						User input
	Timeframe of policy						User input
	Years of early replacement						User input
	Impacted efficiency classes						User input

[2] Electricity prices are Member State specific and derived as the mean value from 2015 to 2023 (non-household consumers. All taxes and levies included. Eurostat 2024b If more accurate data are available, the user can overwrite the figures provided in the tool.

3.3 Conceptual model

Impact modelling is vital for estimating impacts of new legislation. Traditionally, impact assessments on the European level carried out under the Ecodesign Directive have been conducted using the EcoReport Tool (European Commission 2014) at the individual product level, and a detached stock model logic.

As EU product regulation shifts towards considering innovative policies (such as those related to circular economy, e.g. lifetime changes), modelling approaches need to be updated. The Methodology for Ecodesign of Energy-related Products (MEErP) **is being revised** to better reflect these aspects, including updates to the EcoReport Tool for assessing circular economy measures at the product level. However, as Barkhausen et al. (2023) note, there's no dedicated tool for scenario analysis yet and it's unclear if a model will be provided to scale up individual product results to the stock level. With the adoption of novel policies, modelling becomes complex, necessitating a consistent approach for harmonizing EU product policy across product groups.

Academic research has primarily focused on assessing product policies related to recycling. However, as soon as we consider changes in product lifetime, such as early replacement or repair, the modelling becomes complex. Not only energy consumption, but also material flows become increasingly important to consider. Early replacement can be relevant, even if it seems counterintuitive from an environmental perspective, particularly for products where the use phase is the dominant environmental impact and if replacements offer significant performance improvements (Barkhausen et al. 2023).

Material Flow Analysis (MFA) and **Life Cycle Assessment (LCA)** each offer unique strengths in assessing the impact of policies. MFA quantifies the stocks and flows of materials within a specified system, providing a comprehensive understanding of material usage, losses, and circularity. It's particularly suitable for long-term macro-scale system analysis. However, MFA does not account for associated environmental impacts. On the other hand, LCA is a standardized methodology for assessing the environmental impacts associated with a product or service over its entire life cycle. It can provide a more detailed view of a variety of environmental impacts (impact categories such as climate change, particulate matter formation or acidification) at the product level. However, LCA is typically performed at the product level without considering material stocks. The combination of MFA and LCA can provide a more comprehensive and holistic assessment of the impacts of policies. **Combining MFA and LCA allows for a holistic assessment of both the material flows and the environmental impacts associated with a policy.** This provides a more complete picture of the policy's impact. While MFA provides a macro-level view of material flows, LCA provides a detailed assessment at the product level. Combining these approaches allows for a detailed assessment of the impact at both the market level and the product level (Barkhausen et al. 2023).

Therefore, the **EU-M³** employs a layered approach where material and environmental impacts are deduced from motors on the market via a motor database. This database defines physical properties for motor variants (representative motors representing a large share of motors on the European market, such as energy consumption and material composition). The individual motor data is used to build up the stock model which allows for the assessment of the impact of policy interventions on the entire market over time.

The **EU-M³**consists of three main components (see Figure 3): a **conventional stock modelling**, a **product database**, and an **environmental assessment** which in the EU-MORE context consists of emission factors (see Figure 3). The stock modelling works with a given stock as an input value from which inflows and outflows are calculated. The product database serves as an integrator between the stock modelling and the environmental assessment, defining material intensities and other characteristics for each product variant. The environmental assessment is kept lean as mere emission factors for global warming potential (measured in kg CO_{2eq}), which converts the energy consumption into environmental impacts (Barkhausen et al. 2024).

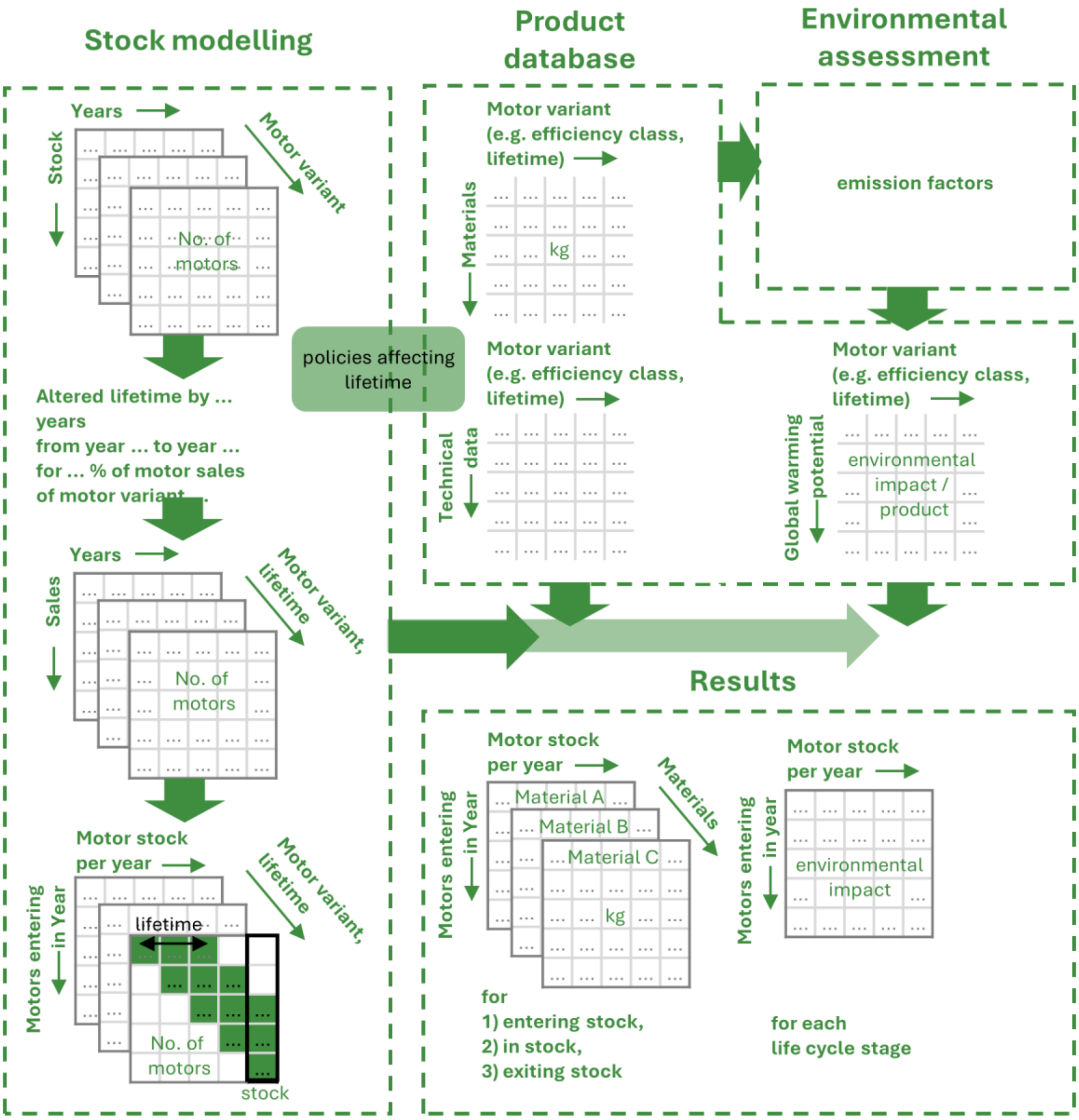

Figure 3 Schematic representation of the modeling logic (Barkhausen et al. 2024)

3.4 Representation of results

Results are presented using a balanced combination of data visualization and factual information, aligning with theories of effective data communication. This approach caters to different information processing preferences, enhancing the comprehension and usability of our findings.

Data visualization, through graphs showing temporal developments, serves as a powerful tool for conveying complex trends and patterns in a digestible format. It enables stakeholders to grasp the overarching narrative of our findings quickly, visually mapping the trajectory of variables such as cost savings or CO_2 emissions over time.

Complementing these, specific numerical values are provided to quantify key outcomes. These factual data points offer precise, unambiguous information, allowing for detailed analysis and interpretation. They provide the concrete numbers that underpin the visual narrative, such as exact amounts of cost savings or CO_2 emissions at specific points in time.

In presenting results, it can be difficult to avoid information overload. To address this, the information displayed was curated, focusing on key figures that capture the assumed most relevant aspects. Supplementary data, like additional figures and different graphs, are provided separately, housed in a distinct sheet within the Excel file. This allows users to delve deeper into the data if they wish, without cluttering the central narrative.

In conclusion, the approach to present results uses both visual and factual elements, offering a comprehensive yet user-friendly overview of the impact assessment. This approach ensures that results are not only accessible but also actionable, enabling decision-makers to leverage the **EU-M³** effectively in their policy-making process.

3.5 Technical implementation

It was chosen to implement the **EU-M³** in Excel, a decision primarily driven by considerations of accessibility and ease of use, particularly for policy makers who may not be familiar with more complex modelling environments like Python.

Excel's widespread recognition and usage across diverse industries make it a practical choice for stakeholders including policy makers, researchers, and industry representatives. Its user-friendly interface, devoid of a steep learning curve, contrasts Python's need for substantial programming knowledge. The choice of Excel guarantees that the **EU-M³** can be accessed, understood, and potentially modified by a broad spectrum of users, beyond those with programming skills alone.

However, we acknowledge Excel's limitations. Handling very large datasets or complex calculations can make Excel models cumbersome and slow. The absence of a formal coding structure can challenge change tracking or troubleshooting. But for this project, despite these constraints, Excel offers the best balance of accessibility, ease of use, and functional capability. It promises the widest possible audience for the **EU-M³**, thereby enhancing its utility and impact. More sophisticated functions offered by complex modelling environments might limit the audience capable of effectively engaging with the **EU-M³**.

In conclusion, Excel's mix of simplicity, accessibility, and sufficient functionality makes it the most suitable platform for the **EU-M³**.

4. Policy selection & impacts

4.1 Policy selection

The selection of policies to be used in the **EU-M³** has largely been based on the deliverable D2.2 (Review of past policies). Therein, past and current policies on electric motors are reviewed across the 27 EU Member States. The review is conducted through a literature review of publicly available information from national government websites, evaluation reports, data sources and impact studies. It is further verified through interviews and assessments by national experts. In particular, the report provides an overview of the main policy measures in place across the EU, detailing the general characteristics, impacts and lessons learned from each measure. It covers 64 measures across the EU related to the replacement of inefficient electric motors (Faassen et al. 2024).

The report also provides a detailed analysis of the impact of these measures, identifying Germany, Austria and Denmark as the leaders in terms of the number of measures implemented and an overall focus on subsidy-based policies and mandatory standards for electric motors (Faassen et al. 2024).

The report concludes with a **call for more targeted motor replacement policies**, highlighting that the adoption of such policies can make a significant contribution to achieving energy savings targets, stimulating economic growth and strengthening energy security (Faassen et al. 2024).

Furthermore, other parameters have been taken into account for the selection of appropriate policy measures to be used in **EU-M³.** These were among others the identification of barriers, success factors, cost/effectiveness ratios and ease of implementation by policy makers.

As a result, the policies identified as most suitable for estimating their impact using the **EU-M³** are financial policies that encourage the replacement of old motors with higher efficiency one's. There are different types of such financial policies, and particularly subsidy schemes and tax incentives (in combination with voluntary agreements) proved to be widespread and effective based on the EU-MORE policy analysis. In addition to financial policies, there are non-financial policies such as information campaigns which can complement other policies or work as a stand-alone measure to impose behavioural changes. In terms of assessing the impacts, the impact of such non-financial policies is much more difficult to determine. To provide nonetheless an orientation of such policies in the model, **cost-effectiveness ratio's** of existing programmes are used to provide indications on how such programmes might compare to financial one's (more information in chapter 5).

- **Financial policies**
    - **Subsidy scheme**: This policy measure incentivizes the replacement of old, inefficient motors with new, more energy-efficient ones. It involves offering financial rewards or subsidies for the disposal of old motors. This policy measure aims at tackling **high upfront investment cost** when replacing old motors with new and efficient ones, especially in cases where the investment is not considered particularly economically favorable but carries high energy saving potential.
    - **Tax incentive in combination with voluntary agreement**: This policy measure provides **tax incentives or rebates** on new high efficient motors to companies that replace old motors with more energy-efficient ones. The aim is to reduce the financial burden of motor replacement and to encourage the use of energy-efficient technologies. This policy measure aims at tackling - among other - organizational barriers, including resistance to change. Such policy measures are

usually part of Voluntary Agreements in the industrial sector and could boost investments which are economically favorable.

- **Non-financial policy**
  - **Information campaigns and capacity building**: These policy measures aim to raise awareness of the benefits of replacing old motors with more energy-efficient ones. It may include the dissemination of information through various channels such as workshops, seminars, online platforms and promotional materials. Integrated programs may be further enhanced to include the offer of free or subsidized energy audits to allow particularly small and medium-sized enterprises (SMEs) to prioritize energy saving investments[3].

For each policy type, subchapters 4.2 and 4.3 provide a general description of how they work, followed by the identification of success factors when implementing such policy (in bullet form), available cost-effectiveness ratio's and examples of good practice. The good practices are not limited to the EU but also include examples from other countries such as Switzerland or India.

4.2 Financial policies

4.2.1 Subsidy scheme

General description / when to use such a policy measure

This policy measure incentivizes the replacement of old, inefficient motors with new, more energy-efficient ones. It involves offering **financial rewards or subsidies** for the replacement of old motors with new and more efficient ones. This policy measure aims at tackling high upfront investment cost when replacing old motors with new and efficient ones, especially in cases where the investment is not considered particularly economically favorable but carries high energy saving potential[4]. Therefore, the grant/subsidy scheme should preferably support investments with a payback time of more than 3-4 years. To maximize the impact of such a policy measure, it should target primarily old motor systems (i.e. > 15 years old) and end-users with high electricity consumption (i.e. > 500 MWh/yr) (Werle 2024).

Such financial instruments have proved over time valuable in introducing existing high-efficiency products and new technologies to the market. They lower the initial costs of energy efficiency projects, enhance the financial return on investment, and improve cash flow, which boosts investors' access to debt financing. Additionally, these incentives can increase awareness and trust in energy-efficient technologies, though they are often constrained by budgetary limitations. They also leverage investment, reduce administrative costs (as there are a relatively small number of manufacturers and distributors compared to consumers) and increase product availability at the point of sale and therefore accelerate market transformation (Kulterer et al. 2014).

[3] Those SMEs that do not fall under the energy audit obligation of Article 11 of the EU Energy Efficiency Directive („Member States shall ensure that enterprises with an average annual consumption higher than 10 TJ of energy over the previous three years, taking all energy carriers together, which do not implement an energy management system are subject to an energy audit") (European Commission 2023).

[4] It should be noted that for calculating savings according to Annex V (m) of the EU Energy Efficiency Directive "savings are claimed only for the period until the end of the average expected lifetime of the product or vehicle to be replaced" (European Commission 2023)

In cases where there is a need of reducing greenhouse gas emissions more quickly than the natural replacement cycle allows, policy makers may consider implementing such financial incentives to promote the accelerated replacement of outdated, inefficient electric motors and motor systems. This approach aims to facilitate a swift transition to high-efficiency electric motor systems in the market (Waide and Brunner 2011).

Subsidy schemes may also be applied in situations where tax rebates do not serve as a significant incentive for businesses, since non-transferable tax rebates are only effective when profits are generated (European Commission 2022).

Subsidy schemes are especially beneficial for (at least partially) mitigating the risks faced by capital suppliers, including the initial costs associated with third-party investments and the challenges in assessing the quality and performance of funded projects. Therefore, such instruments may be beneficial in assisting companies gaining access to private capital. Such policy measures can also effectively tackle behavioral and organizational barriers, as investments in energy efficiency are often seen as non-core activities. These investments compete with other opportunities that have more clearly defined risks and returns for business decision-makers or are deemed more strategic and integral to core business functions. Grants and subsidies lower the overall investment cost making the energy efficiency investment more economically attractive (European Commission 2022).

Finally, such a policy measure would be particularly useful in assisting SMEs (those not adressed under the EU Energy Efficiency Directive (European Commission 2023)) realizing such energy efficiency gains. SMEs tend to be more hesitant to invest in energy efficiency, as the likelihood of such investments depends on factors like energy intensity, company size, and investment profitability. In addition, it is essential to provide incentives that encourage SMEs to prioritize investment decisions taking into account full life-cycle cost instead of purchase cost only (Pasquier and Saussay 2012; Herce et al. 2024).

Success factors

- Define clear criteria for the efficiency of qualifying product (International standards or national MEPS could assist in this direction)
- A clear definition of the grant or rebate amount should be provided, specifying any variations based on product specifications or usage, such as motor size
- Ensure the program is not too complicated (in terms of eligibility criteria of beneficiaries, application process, provision of funds to the beneficiaries etc.)
- Appropriate program duration. The duration should be sufficiently long for market participants to understand the instrument and make informed decisions, yet short enough to prevent the grant or rebate from distorting the normal pricing of the product, which could result in higher costs than if the instrument were not in place
- Engage all stakeholders, especially during the design phase of the policy
- Develop and implement an appropriate monitoring and evaluation mechanism to assess the effectiveness of the policy measure (Kulterer et al. 2014)
- Programme awareness; Programmes that are largely known (word to mouth) among the target groups are expected to be in greater demand
- Qualification of involved consultants; Sufficient expertise of consultants, ability to carry out analyses is crucial to the success of the program (Werle 2024)
- All policy actions should be accompanied by information and awareness raising campaigns, informing stakeholders such as policy makers, plant operations, production, maintenance

and energy managers, on the significant savings potential made available by improving the energy performance of electric motor systems (Almeida et al. 2023)

- Linking to results from dedicated energy audits, to maximize impact

Cost effectiveness

The subsidy rate should be selected carefully in order to facilitate investments on the one hand and on the other hand to prevent negative side-effects from such policies including rebound effects and free-riders. One common option is having the financial incentive equal the price difference between the lower-efficiency and the higher-efficiency option (Kulterer et al. 2014).

Cost/effectiveness depends on several factors including the co-funding rate of subsidies. In general, and based on available data from past programs, the cost-effectiveness of such policy measures ranges from approximately 0.01 – 0.10€ of public subsidy per kWh saved over the lifetime of equipment (Faassen et al. 2024).

Good practices

Good Practice 1: Energy Efficiency Promotion Plan (PPEC) (Portugal)

The Energy Efficiency Promotion Plan (PPEC) consists of an incentive mechanism that aims to promote actions to improve efficiency in electricity consumption. To this end, suppliers, network operators and entities that promote and defend the interests of electricity consumers in Portugal propose measures (tangible and intangible) that go through a selection process managed by ERSE (Regulatory Entity). These actions are aimed at electricity consumers in the various market segments, such as Industry and Agriculture, Commerce and Services, and Residential. The selected actions are funded through a tariff surcharge included in the energy bill (Global Use of the System). The PPEC had its first edition in 2007 and it is now in its 7th edition.

Measures relating to electric motors were approved in the 4th edition (2011/2012), 5th edition (2013/2014) and 6th edition (2017/2018). No measures for electric motors are included in the current edition.

Regarding the 6th edition (2017/2018), it included a measure to promote the installation of High Efficiency Motors, within the 0.75 kW to 400 kW power range, in the manufacturing, agricultural and fisheries sectors as a replacement for low efficiency motors (**motors of efficiency class below IE1**) was approved. The objective was to replace these inefficient motors with IE3 or IE4 motors.

A financial incentive of **51.1% of the average new motor price** (including installation costs) was given. The measure also foreseen a rapid assessment of the use profile and load of the motor to ensure a correct dimensioning of the replacement motor.

The measure had a budget of 896 767€ for the replacement of 420 motors. The estimated electricity savings generated by the measure were of 115 GWh with a corresponding reduction of GHG of 43 thousand tCO_{2eq} and a cost-effectiveness ratio of 0.008€ / kWh saved over the lifetime of the equipment.

Additionally, the collection of the old motor for recycling was foreseen, with the transportation costs of the new motor being covered by the scrap value of the old motor (Faassen et al. 2024).

Good Practice 2: ProkiloWatt (Switzerland)

ProKilowatt is a sector-wide program initiated by the Swiss Federal Office of Energy (SFOE). The program is based on competitive calls for tenders aiming at reducing electricity consumption by – among other - companies in the industry and services sectors through the financial support of measures to increase its efficient use. It supports projects and programs that meet the specified requirements and save as much electricity as possible per provided Swiss franc. The source of the funding is an electricity network surcharge which accumulates up to 70 million Swiss francs per annum.

One of the key elements of Prokilowatt is that it s**ubsidizes energy efficiency measures that are not considered economically viable.** Therefore, projects need to have a payback time of more than 4 years to be eligible for funding.

Motor systems accounted for 29% of the total investments of the program, resulting in 3.2 TWh saved over the equipment lifetime.

To minimize the risk of free-riders participation, Prokilowatt has established a maximum subsidy of 30% the investment cost. The annual budget of the program amounts to about 50 000 000€ per year. During the period 2010-2023, the program has funded 956 projects providing 430 000 000€ in public spending. As a consequence, 14.5 TWh of electricity have been saved over the lifetime of equipment, resulting in a cost-effectiveness ratio of 0.03€ of public subsidy per kWh saved over the lifetime of equipment (Wunderlich 2024; Werle 2024).

Good Practice 3: **National Motor Replacement Program (India)**

India's **National Motor Replacement Program (NMRP)** is an initiative aimed at promoting energy efficiency and reducing energy consumption in the industrial sector. The program, led by Energy Efficiency Services Limited (EESL), a joint venture company of four public sector enterprises of the Indian Ministry of Power, United for Efficiency and the International Copper Association (ICA) India—among other implementation partners, focuses on replacing inefficient motors with premium-efficiency IE3 motors. The NMRP works to address several systemic barriers that have challenged the adoption of energy-efficient motors. These range from issues of awareness among companies and consumers about the benefits and technological options available for energy-efficient motors to financial barriers due to high upfront costs of energy-efficient motors with limited market availability (Motor Efficiency Global Alliance 2024).

To overcome these barriers, the NMRP employs a combination of strategies:

- Demand Aggregation: By pooling the demand for energy-efficient motors, the program helps lower costs and encourages manufacturers to produce higher volumes of high-efficiency motors.
- Awareness Creation: The program conducts outreach activities to educate and inform stakeholders about the benefits of high-efficiency motors and energy conservation.
- Finance: The program facilitates financing options for industries to help them cover the upfront costs of motor replacement and in making informed decisions (Motor Efficiency Global Alliance 2024).

More specifically, the program, as part of an integrated approach is using the following activities to address most of the common barriers regarding early motors' replacement in the industry:

- Price reduction through bulk procurement

- Easy and innovative financing options for customer, with EESL taking care of entire upfront cost
- Pilot studies for major motor ratings were conducted to establish a deemed savings model
- Awareness programmes on technical and commercial aspects conducted with ICA India as the outreach partner
- Reduced delivery time of motors by fixed delivery timeline after placing Letter of Intent
- Inclusion of add-on features, such as extended warranty, after sales support and option for walkthrough audit services, to make the proposition more attractive
- Exploring synergies in demand aggregation through empanelled partners
- End-user awareness programme to address resistance to change (U4E et al.)

The first phase of the National Motors Replacement Programme [NMRP] was aimed at understanding the market's acceptance of IE3 motors and using the lessons learnt to prepare for the subsequent phases of the programme. Looking at the outreach achieved through NMRP 1.0 during 2018-19, the industries which have participated have seen positive results from replacing their old, lower efficiency motors (IE1 and below), with premium efficiency (IE3) motors.
The overall estimated savings, in terms of energy, cost and emissions reduction, through replacement of approximately 5 000 motors in both larger companies and the SME sector, amounts to 9 150 MWh on an annual basis (U4E et al.).

4.2.2 Tax incentive in combination with voluntary agreements

General description / when to use such a policy measure

This policy provides tax rebates or other tax incentives to companies that replace old motors with more energy-efficient ones. The aim is to reduce the financial burden of motor replacement and to encourage the use of energy-efficient technologies. This policy measure aims at tackling - among other – organizational barriers, including resistance to change. Such policy measures are usually part of Voluntary Agreements in the industrial sector and could boost investments which are economically favorable. Therefore, such a policy measure should preferably **support investments with a payback time of less than 3-4 years**. To maximize the impact of such a policy measure, it should target primarily old motor systems (i.e. > 15 years old) and end-users with high electricity consumption (i.e. > 500 MWh/yr).

Voluntary agreements are customized, negotiated commitments between public authorities and individual companies or groups of companies. These agreements set specific targets and timelines for improving energy efficiency and outline corresponding rewards and penalties. According to the International Energy Agency, a Voluntary Agreement is "**a contract between the government and industry, or negotiated targets with commitments and time schedules on the part of all participating parties**"

Financial incentives including tax rebates have been the most common motivating factors for Voluntary Agreement participants to encourage the uptake of energy-efficient motor systems. A tax rebate is essentially a refund of taxes that have already been paid, or it's a return of a portion of taxes paid based on specific criteria or circumstances. Other tax incentives include: Tax credits, such as permitting the full or incremental costs of energy efficient motor systems to be deducted from taxable corporate profits, or reducing VAT. These incentives have the same impact as direct grants but offer the advantage of **simplified applications**, as they utilize the existing tax administration system. However, like grants, they still impose a burden on public budgets (Rezessy and Bertoldi 2011).

Other incentives used are deferred legislation and/or more flexibility in the planning and execution of energy efficiency policy and investments on a company level. Voluntary Agreements usually follow the carrot-and-stick approach, therefore along with the incentives provided, penalty mechanisms discourage non-compliance of participants with their commitments. Common threats and penalties are withdrawal of eligibility for the incentive (e.g. subsidy or tax rebate), often combined with retroactively paying back the financial aid already provided.

The main **elements** of Voluntary agreements are the following:

- An ambitious, yet attainable binding commitment from the participating companies associated with energy efficiency quantitative targets and a specific payback period or timeframe
- A binding commitment from the public authorities in supporting the participants, such as, the supply of the planned incentives and providing practical support in developing energy efficiency plans and actions
- An effective monitoring and evaluation system; such a system is critical to the continuation and improvement of the program and to ensure compliance of the signatories with the program rules (Kulterer et al. 2014)

The main **advantages** of voluntary agreements are:

- Voluntary agreements are particularly useful when addressing motor systems as they are widespread in manufacturing environments, but their applications vary widely. System optimization cannot be fully achieved through “one size fits all” approaches.
- They are extremely flexible and able to deliver tailor-made plans and solutions for each industrial sector or even a single participating company.
- With effective monitoring system in place, Voluntary Agreements can offer a high level of assurance that the program objectives and targets will be achieved.
- From the industry perspective, they tend to be more acceptable than regulatory / legislative requirements.
- They can be implemented alongside other policy measures, such as ETS (emissions trading schemes), or in sectors with inadequate regulatory/legislative framework.
- They are particularly relevant for industrial sectors that rely heavily on energy demand from motor systems (e.g. the hospitality sector, to cover heating and cooling needs) (Kulterer et al. 2014).

Voluntary Agreements have also proved to be very useful from the perspective of **public authorities** as they often lack detailed knowledge of optimal technologies and their associated costs for motor systems, which means they may overlook the unique challenges faced by individual companies (Kim and Liu 2020).

Moreover, public authorities frequently elect to utilise Voluntary Agreements due to their inherent capacity to facilitate the implementation of obligations that would otherwise be fraught with contention and, in some instances, impracticable to enforce in a rigid manner through legislative means. (Rezessy and Bertoldi 2011).

Voluntary Agreements offer several more advantages to the public authorities, including:

- they are more flexible and quicker to introduce compared to regulations,
- they are easier and quicker to update and upgrade than regulations thus allowing to better follow technological evolution,
- unless voluntary agreements depend significantly on subsidies and tax exemptions, they can help alleviate the strain on public budgets (Rezessy and Bertoldi 2011).

On the other hand, Voluntary Agreements may suffer from a number of **risks**, including:

- Easy to achieve, lenient obligations and targets that require little more than business-as-usual. This can occur when public authorities have limited knowledge on establishing the costs incurred for the industry and the saving potential, or in cases of regulatory capture.
- Not meeting the program targets due to lenient penalties for non-compliance with the program requirements.
- Free riding. This situation can arise when an industry association is involved in the agreement. There may be a case where, some individual companies may "free ride" on the efforts of others to achieve the targets set at the subsector level. These free riders benefit from the reputation generated by the program while contributing minimally, if at all, to meeting the specified targets, if they are formulated on a sector basis rather than for individual companies.
- (Any) subsidy rate and other financial incentives should carefully be selected in order to facilitate investments on the one hand and on the other hand to prevent negative side-effects from such policies including rebound effects and free-riders. One common option is having the financial incentive equal the price difference between the lower-efficiency and the higher-efficiency option (environmentally relevant additional investment cost).
- Tax incentives might not always be a strong incentive for businesses as these non-transferable incentives only work when a profit is made (Rezessy and Bertoldi 2011).

Voluntary Agreements can also prove a valuable tool to **support SMEs** on achieving high energy efficiency gains. This can be achieved in many ways:

- Voluntary Agreements may require participants to implement Energy Management Systems (EnMSs) and energy audits to reduce their electricity consumption through the replacement of old motor systems. In Japan, a survey of approximately 1 000 companies revealed that SMEs in industries with voluntary action plans were much more likely to achieve their carbon emission targets compared to companies in sectors without such plans. This confirms that **voluntary action plans are effective** in overcoming information barriers for SMEs (Herce et al. 2024).
- Experience from Sweden and Germany also demonstrate that Voluntary Agreements enforce industrial SMEs to implement energy management systems and energy audits. As a result, the participating SMEs may benefit from applying for a rebate on energy tax, which has proved to be successful.
- Voluntary Agreements are also very useful for participating SMEs in addressing information and competence-related barriers. As SMEs suffer more from lack of information comparing to large companies, they may achieve higher relative energy savings through tax rebates (Herce et al. 2024).
- Voluntary agreements facilitate access to information, and the requirement to implement certain identified measures through the mandatory implementation of EnMS, helps overcome

key organizational and behavioral barriers, such as time constraints, conflicting internal interests, lack of interest and competing priorities among employees.

- A good practice demonstrating the usefulness of Voluntary Agreements to SMEs are the Energy Efficiency Networks (EEN) in Germany (Effizienz Netzwerke 2021). EENs help participating companies overcome barriers to implement energy saving measures, including information and competence-based barriers. EENs also promote the exchange of energy efficiency experiences in moderated meetings and consultations with energy efficiency experts. As a result 75 PJ have been saved in primary energy from 2014 to 2020 (European Commission 2022). Furthermore 12% of reported implemented measures are related to motor driven system (Rohde et al. 2020).

Success factors

- The voluntary agreement scheme must provide a strong economic incentive (e.g. through the provision of tax rebates) to participants in order to make the scheme attractive.
- To promote the improvement of old motor systems and/or the replacement of old motors with new and efficient ones, electricity consumption should be explicitly mentioned when designing Voluntary Agreement programs. That would engage participating companies to include old motors replacement in their plans as **motor systems are responsible for more than 70% of industrial electricity consumption** (Kulterer et al. 2014).
- Purchasing criteria should take into account efficient motor systems.
- Efficient motor systems could be explicitly identified as a primary target for energy audits and EnMSs.
- Voluntary agreements should offer training and other capacity building activities on the optimisation and maintenance of motor systems.
- In order for a VA program to be successful, an effective and credible system of monitoring of compliance and evaluation of results needs to be implemented. Reporting has to be transparent by making it as public as possible.
- Third party verification would further promote transparency of the program and increase credibility of results. Moreover, such a practice can reduce the administrative burden and may reduce associated cost for public authorities depending on design.
- Higher compliance with the program requirements and credibility of results could be achieved through spot checks by the public authorities or mandated scientific verifiers.
- Strong political will and engagement of necessary resources is of outmost importance.
- Due to the voluntary nature of VAs, special interest and effort should be given to the development of a culture of trust and cooperation between all participating parties, to ensure an agreement with shared responsibilities
- Public authorities should employ a dedicated team with the necessary expertise to run the program. Capacity building activities could be thus very effective.
- Credible and enforceable mechanisms need to be established to discourage non-compliance, including sanctions or retroactively paying back the financial aid already provided.
- Supporting measures, such as subsidized energy audits, technical assistance, information, would greatly facilitate the effective execution and success of agreements.
- The program targets should be fairly ambitious yet attainable for the participating companies, to ensure effectiveness of the program.

- Provision of a clear and adequate timeframe for the program (Rezessy and Bertoldi 2011; Cornelis 2019).

Cost effectiveness

Cost/effectiveness depends on several factors including the incentive provided to the beneficiaries (tax based incentives, co-funding rate of grants/subsidies etc) and therefore varies largely. In general, and based on available data from past programs, the cost-effectiveness of such policy measures should have a range of approximately 0.01 – 0.10€ of public subsidy per kWh saved over the lifetime of equipment.

Good practises

Good Practice 1: Energy Investment Allowance (The Netherlands)

EIA (Energie-**investeringsaftrek**) stands for Energy-Investment Allowance and allows companies to receive a tax deduction for investments made that are included in the Energy List (referred to as 'company resources') and that result in substantial energy savings.

The measure was introduced by the Dutch Ministry of Economic Affairs and Climate (EZK) and is administered by the Netherlands Enterprise Agency, 'Rijksdienst Voor Ondernemend Nederland' (RVO) and the Tax Administration 'Belastingdienst'. The program is ongoing and running for more than 25 years since 1997.

Through the EIA companies can receive a tax deduction for clearly defined investments and for tailor-made investments that result in substantial energy savings. With a minimum amount of 2 500€ and a maximum investment amount of 136 000 000€. **Companies can deduct 45.5% of the investment costs from the taxable profit.** This is possible **on top of the usual depreciation**. These investments are described as 'company resources' and are **specific to technologies that are included in the annually revised 'Energy List'**.

Specific to EU-MORE is the inclusion on the Energy List of investments in HR electric motor

for use in:

a. electric motor, designed for direct connection to the electricity grid
b. Ex eb electric motor (high safety motors), designed for direct connection to the electricity grid,
c. electric motor, designed for variable speed and not connected directly to the electricity grid

and consisting of:

a. 2, 4 or 6-pole electric motor with a nominal power of less than 75 kW or greater than 200 kW or 8-pole electric motor that meets the IE4 efficiency class measured in accordance with NEN-EN-IEC 60034-30-1:2014;
b. Ex eb electric motor, which meets the IE3 efficiency class measured in accordance with NEN-EN-IEC 60034-30-1:2014;
c. electric motor, which complies with the IE5 efficiency class in accordance with NVN-CLC-IEC/TS 60034-30-2:2021, electronic speed control, (possibly) integrated gear unit (not being a worm gear unit).

Synchronous motors (including direct current motors) can be reported under category c.

Apart from the expenses for the company resource, all expenses that are technically necessary and purely for that company resource are expenses eligible for the EIA. These are usually the material and fitting expenses of the company resource.

The budget for the EIA in 2023 is 249 000 000€ with a 45.5% rate deducted from taxable profit. The government writes in the Budget Memorandum and the accompanying budgets that due to the increased inflation and energy prices, companies are making extensive use of the EIA. But even before 2022, according to the government, applications for the scheme increased and this trend will continue. To give companies extra support and to accommodate the higher demand, the government is structurally increasing the budget for the EIA.

The effectiveness of the EIA, measured as energy savings per euro of tax expenditure, appears to be high compared to other schemes. Even considering freeriders, the benefits per euro of public money are still very decent. Converted to euros per tonne of CO_2 saved emission, it concerns a subsidy 'effectiveness' between 2012 and 2017 of an average **of 14€ per ton of CO_2** and **when taking into account free-riders between 21 and 46€ per tonne of CO_2**. This is, compared to other grants, a relatively cheap way to save on CO_2 (Faassen et al. 2024).

Good Practice 2: Voluntary agreements with industry (Belgium, Region of Flanders)

This is a measure of the Region of Flanders. In a first step, it had two components, covering the period 2003-2013: the Audit covenant and the Benchmark covenant. In 2014, as a third component new 'energy policy agreements' were signed for the period 2015-2020 ('Energiebeleidsovereen-komsten 2015-2020"). The measure is since extended until 2025.

It concerns both ETS and non-ETS energy intensive companies (primary energy consumption > 0.5 PJ).

By mid-2016, 338 establishments had joined the agreement, which represent over 90% of the industrial energy consumption.

The companies joining the agreement commit themselves:

- to have an **energy audit** carried out every 4 years;
- to set up an energy Plan on the basis of the energy audit, containing an analysis of the specific energy consumption of the establishment and identifying the profitable measures (those with an IRR after taxes of 14%) for reducing the specific energy consumption;
- to carry out all profitable investments of it;
- to annually report on the measures taken, studies and recalculations of the potential of profitable measures;
- to annually report on the energy consumption, the CO_{2eq} emissions and their evolutions.

In counterpart, the Flemish Region commits itself not to impose other specific Flemish measures (such as an energy or CO_2-tax, going beyond European obligations) to the companies fulfilling their obligations. It will also simplify the administrative burden of companies by not requiring any additional reporting on energy.

The companies joining the agreement are considered as automatically satisfying all the obligations on energy plans of the government Energy Decree of 19 November 2010.

The companies involved undertake to carry out an energy audit and draw up an energy plan to improve energy efficiency. In the first phase, (not later than 4 years after acceptance of the energy plan), **they must implement all cost-effective measures with an IRR of at least 15% after tax**. In the second phase, not later than 4 years after the acceptance of the updated energy plan, companies must implement energy efficiency measures with an IRR of at least 13.5%.

Target-group companies that do not sign or implement the covenant lose the right to the degressive application of the Federal electricity contribution;

From the 2009 tax year, companies that have signed an energy policy agreement with the Flemish Authority are fully exempted from property tax on new equipment and machinery. No specific figures are available related to motors specifically (Faassen et al. 2024).

Good Practice 3: **PFE – Program for energy efficiency (Sweden)**

PFE was a program to improve energy efficiency in Swedish energy-intensive industry through a new law that regulated long-term agreements between the state and energy-intensive companies. The program was running for 11 years (2004 – 2015) and the responsible authorities were the Swedish Energy Agency (SEA) and the Ministry of Climate and Business (RSE).

The law set a number of qualitative requirements for companies to achieve within the five-year programme period. In exchange, companies received a reduced electricity tax of 0.005 SEK/kWh.

The companies' commitment was to:

- **implement and certify an energy management system (EMS)**,
- carry out a comprehensive energy audit,
- implement electricity efficiency measures to achieve the company's energy efficiency targets/commitments,
- Introduce energy considerations in purchasing and design processes.

After completing the five-year cycle, from 2009 onwards companies were able to participate in a second programme cycle. Most companies completed the programme in 2014.

Measures that can be related to motor drives touch many different areas of action and account for about 25% of the efficiency improvements - **11% of which in pump systems and only 2% of measures relating to motor replacement**.

The companies have reported that more than 70 per cent of the implemented measures had a payback period of less than 3 years.

The programme attracted more participants than expected with more than 100 companies participating in the PFE. Virtually all energy-intensive companies with an energy consumption above 100 GWh per year participated, but only a few energy-intensive SMEs.

The reported electricity efficiency improvement of 3 TWh per year corresponds to a 10% reduction in the total electricity consumption of the companies. Estimates made by the companies and assessments in academic reports show that about one third of the efficiency gains probably occurred without the PFE. This gives a net result of 2 TWh per year. **Of these savings, around 25% are attributable to measures in motor driven systems (Fans, compressors, pumps, refrigeration systems, etc.) which corresponds to around 500 GWh per year.**

Although no information was found specifically related to measures implemented on motor systems, the overall cost-effectiveness of the 2 500 measures was positive with companies reporting an average payback of less than two years. Approximately SEK 2 billion (177 000 000€) were invested within the program.

According to the Swedish Energy Agency report "10 år med PFE":

"Fundamental to the positive results of the PFE was that the state, through the tax reduction, showed a clear direction on the issue and at the same time took into account the global competitiveness of the energy-intensive industry. The companies' management teams recognised this and in turn took responsibility for the energy efficiency work in the companies."

"The core of the PFE was the requirement to implement an energy management system. This increased the systematic nature of the change process, which led to an organisational change in the companies. […] above all, the work on energy efficiency became an issue that was present in the daily work." (Faassen et al. 2024)

4.3 Non-Financial Policy

4.3.1 Information campaigns and capacity building

General description / when to use such a policy measure

Besides economic barriers, some of the most perceived barriers for the replacement of old motors and the optimization of old motor systems include information, awareness, behavioural and organizational ones.

It is a common view that energy efficiency is often overlooked by management because it is not a core business activity and it is thus not worth much attention. Therefore, management attention is usually focused on other areas deemed as more critical to the survival and growth of the firm. Due to low awareness levels, some managers are reluctant to technological changes because they do not know how to implement an energy conservation project or how to quantify energy and financial savings benefits. In many companies there is often a shortage of adequately trained staff, as most personnel are busy maintaining production. Lack of skilled personnel leads to difficulties with respect to installation of new, energy-efficient equipment. The perception of highly bureaucratic procedures to get public financial support is also another obstacle to this direction. Also low motivation levels of employees due to low awareness is another important factor to be considered (Sardianou 2008).

Energy efficiency investment considerations should be embedded into the core business strategy and processes, and clear incentives must exist within companies to assess how energy efficiency savings can improve the competitiveness of their business in the long-term (European Commission 2022).

Information campaigns combined with raising awareness and capacity building activities are a very effective way to address such barriers.

Such a campaign may include and provide:

- Awareness-raising material,
- sharing best-practice case studies.
- energy efficiency awards,
- technical guides and training, or
- tools to optimize motor systems and to assess life-cycle costing (Kulterer et al. 2014).

An information campaign should be designed in a way to adequately target all involved personnel in decision making, i.e. financial, operation, marketing, procurement, maintenance and compliance managers. Executive management support is of course of outmost importance.

The use of case studies to highlight examples of best practice is an extremely useful awareness-raising tool. In this way the target audience, can better identify potential energy efficiency projects and the associated potential benefits.

Awards programs serve as an effective way to highlight energy-efficient technologies and their benefits and can be an integral part of broader communication strategies. These programs recognize and endorse companies for their forward-thinking approaches, often offering financial rewards as well.

Recognition programs have proven to be effective mechanisms for rewarding industrial facilities who participate in public programs to encourage more energy efficient behavior. Recognition programs also “lead by example”, by building greater awareness of the benefits of industrial energy efficiency among companies that may not yet be active. Finally, recognition programs create peer pressure within sectors that encourages more energy efficient practices, as companies receiving awards or other types of recognition seek to use them for competitive advantage (McKane et al. 2007).

Guides can provide a very useful communications tool and complement existing technical material. Guides should usually target energy managers in an organization, or energy consultants in the target sectors, and address specific motor systems, such as pumps, fans, cooling equipment, and compressed air systems. This equips these individuals with the information to make an assessment of the opportunities for, and benefits of, energy efficiency in their own situation. Guides and connected tools should include the following content:

- Basic information on the technology, with a focus on energy efficiency procedures for measuring or methods for calculating the energy demand and other costs of the system.
- Information on possibilities to save energy within the system, including approaches to calculate the energy savings and costs of those measures.
- Information on maintenance and potential energy savings.

Training of key personnel (energy managers, energy technicians, energy auditors) is crucial for the best possible optimization of existing motor driven systems. In general, trainings should include among other, audit guidelines and specific energy efficiency topics, related to the optimization of motor systems and identification of opportunities like the impact of VSDs.

Trainings should be appropriately designed for the target audience and trainers should be experts with extensive experience in this field. Pilot audits and/or tests for each motor system covered should be used as indication of competence, and it is good practice to introduce mandatory follow-up training or exams. For maximum effectiveness at the lowest cost, a train-the-trainer program should be implemented (Kulterer et al. 2014).

Energy saving/system optimization calculators should include the following functions:

- Calculation and quantification of energy and financial savings when replacing a motor with a higher efficient one.
- Estimating the benefits of installing a variable frequency drive on a motor system application.
- Estimating the energy demand of electric motor systems to identify the most relevant motors.

Successful case studies and good practices should be shared with campaign participants, including essential information like sector type, company size, resources necessary to achieve the desired results, ease of replication, budget allocated, energy savings, cost effectiveness ratios, avoidance of carbon emissions and any drawbacks and lessons learnt.

Providing sectoral guidelines, such as the Italian guidelines to conduct energy audits, is an example of capacity-building measures. Another example is the Italian information campaign to promote energy efficiency focused on the benefits of energy audits. In this campaign, the Italian Energy Agency worked together with business associations to provide companies with guidelines and targeted technical advice (Herce et al. 2024).

Finally, it is recommended for policy makers to follow an integrated approach when designing and implementing policy measures to accelerate the replacement of old motors and/or the optimization of old motor systems. Therefore, it should be considered to accompany other policy measures like the provision of financial incentives and voluntary agreements by information and awareness raising campaigns, informing stakeholders such as policy makers, plant operations, production, maintenance and energy managers, on the significant savings potential made available by improving the energy performance of electric motor systems. The campaigns should highlight not only the energy savings possible but also additional benefits that arise from using high-efficiency motors (Almeida et al. 2023).

Success factors

When planning an information campaign, it is essential to:

- Conduct initial research to identify the information gaps that need to be addressed.
- Determine the desired actions from the target audience and select the most effective tools or combination of tools to achieve these goals.
- Plan how the materials will be delivered to the target audience.
- Tailor the content to the specific groups being targeted, ensuring that the presentation style and technical detail are suitable.
- Involve stakeholders, such as trade associations, equipment manufacturers, distributors, and professional groups, in both the development and delivery of the materials.
- Ensure that the materials are accurate, reliable, consistent, and user-friendly.
- Confirm that the costs of developing the materials and implementing the campaign are justified by the potential savings (Kulterer et al. 2014).

Cost effectiveness

Cost/effectiveness depends on several factors including the type of activities involved and therefore varies largely. The cost-effectiveness of such measure is very difficult to predict since many factors such as design, scope and budget can have a high leverage on the outcome. Based on available data from past programs, the cost-effectiveness of such policy measures might be approximated at about 0.005 – 0.015€ of public subsidy per kWh saved over the lifetime of equipment. However, it must be stated that reliability and transferability of these approximations is limited.

Good practices

Good Practice 1: Klimaaktiv (Austria)

The program “klimaaktiv Energy Efficient Enterprises” supports industrial and commercial enterprises in optimizing their energy efficiency with a variety of measures:

- Training and webinars for businesses and energy consultants
- Information and contacts for subsidized business consultations
- Guidelines, fact sheets and assessment tools on operational energy efficiency measures
- Posters and videos to raise awareness among employees
- Networking and exchange for implementing energy efficiency measures

The responsible authority for the program is the Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology. Klimaaktiv is managed by the Austrian Energy Agency, involving a budget of 300 000 – 500 000€, annually.

The klimaaktiv management cooperates with market-partners for specific technologies, e.g. compressed air, variable speed drives, pumps, fans, lighting systems, steam systems and waste heat to answer the need of companies for very detailed and professional support. Information on advanced technologies are spread via newsletters and trainings. Until 2022, approx. 1 000 consultants have been trained in using tools for energy audits and about 300 companies have been awarded by the Minister of Environment for implementing energy efficiency measures.

Regarding energy audit guides, the technological approach of the program has been dedicated to motor driven systems so far: Since 2008 specific PR-materials, tools, and a training concept for consultants for different technologies were developed (compressed air, pumps, fans, steam, cooling systems, lighting, and waste heat, machine tools). In 2015 the program emphasised the different possibilities to meter energy and calculate energy savings. For all technologies the most relevant saving measures are described for a very quick on-site evaluation. For the evaluation of all measures, the necessary data to be collected are stipulated, and rough economic and technical criteria are developed to decide if and how a specific technology component should be improved. Furthermore, a standard report is developed. Consultants and energy managers are trained with this tool and check their company or customers.

Among other, the number of participants which successfully completed the training programs (2008-2022) amounted to:

- 279 for compressed air systems training
- 289 for pump systems training
- 222 for ventilation and air conditioning training

- 161 for steam generation systems training
- 22 for driving systems training
- 11 for machine tools training

Based on the evaluation of the program, klimaaktiv is an outstanding example of an integrative climate protection program which highlights relevant and measurable effects like awareness raising, knowledge transfer, and CO_2 savings (Faassen et al. 2024).

Good Practice 2: OekoBusiness Vienna (Austria)

OekoBusiness Wien is the city's environmental service programme for business companies located in Vienna. Within the framework of OekoBusiness Wien, companies receive a co-financed environmental service package. The amount of co-financing varies depending on the advisory service provided.

Businesses have responded very positively to some of the programme's strong points, including consultancy services, the incentive to make changes, the raising of environmental awareness, the opportunity for a systematic analysis of a business's current situation, and the enhanced company image as a result of winning an award. The innovative impact of the measures proposed was also greatly appreciated by the participating businesses. The high-quality consultancy services provided by OekoBusiness Vienna have spawned a wide variety of new policies and measures.

OekoBusiness Wien funds certain consultancy services to encourage businesses to take action to reduce their environmental impact. In individual meetings consultants develop solutions tailored to the needs of each business in three stages:

- Stage 1: Consultants working within OekoBusiness Wien network conduct an environmental check-up together with the company to find savings potentials and detect environmental weak points in the operation.
- Stage 2: On this basis, the company management can decide to participate in the programme and select a suitable consultancy module.
- Stage 3: Supported by tailored consultancy services and expert input, the company develops its environmental project(s) and starts implementation already during the first year of participation. An independent commission assesses the progress made and takes a decision about the award. All measures taken are documented in OekoBusiness Wien database.

Consultants must fulfil certain criteria and must be listed (OekoBusiness Wien – BeraterInnenpools).

From 1998 to 2021, the OekoBusiness Wien companies have collectively achieved the following savings:

- 170.7 million€ operating expenses saved
- 792 000 t CO_2 emissions avoided; for 2021: 4 596 t CO_2 from total energy use (not only electricity)
- 2.6 TWh final energy savings; for 2021: 21.4 GWh electricity (Faassen et al. 2024)

5. Policy impacts

5.1 Scope of policy modelling

To assess the impacts of policies on EU or Member States level in the area of motor system improvements with the **EU-M³**, policies must be translated into model inputs. The required types of inputs have been presented in subchapter 3.2.

Based on these requirements a theoretical case study shall be provided how this is done in practise and the respective calculation shall be carried out. This is done, on the one hand, to validate the operation of the model and on the other hand, to provide useful insights into projection of European policy impacts on overall energy demand and GHG-emissions.

As presented in subchapter 4.1, financial policies were selected as most relevant for estimating their impact. With subsidy schemes and tax incentives (in combination with voluntary agreements), two different types of such financial policies were presented. However, when translating them into model inputs it becomes evident that their functioning is quite similar. A certain amount of money (most often expressed as a share of the new motor) is provided to the company making use of the measure. The difference is mainly in the way the money is delivered to the company. For subsidy schemes, the money is directly provided to the company, while for tax incentives the money is indirectly provided via reductions in tax payments. More nuanced differences, such as the necessity of company profits for the tax incentives to work (as discussed in subchapter 4.2.2), are important but not directly reflected in the model inputs since data on company revenues will normally not be available to the user of the model. Therefore, the user effectively decides which type of financial policy is represented by the inputs he is choosing (more information is provided below).

Regarding non-financial initiatives such as informational campaigns, these are well-positioned to enhance other policies or serve as independent measures to instigate behavioural changes. However, their impact is considerably more challenging to forecast. The potential designs of such measures span a nearly limitless spectrum, and their effects are heavily contingent upon factors like geographical scope, target audience, and budget. To suggest that it is feasible to precisely evaluate the impacts of behaviour-oriented measures in a bottom-up approach may risk oversimplifying the complexities of reality. Consequently, it was determined that these measures should not be intrinsically calculated. Instead, cost-effectiveness ratios from existing programmes will be used to offer insight into how these programmes may compare to financial ones, without asserting a definitive conclusion.

5.2 Theoretical case study

5.2.1 Introduction and user inputs

As a case study example, we choose a financial scheme for a hypothetical country representing the EU average (in terms of electricity production corresponding to the order of magnitude of e.g. Belgium or the Netherlands). The funding program is designed with a volume of 2 000 000€ and a funding rate of 50% per motor[5]. This is in alignment with the funding rates of subsidy schemes such as the Portuguese

[5] If instead a tax incentive is modelled, the funding rate would most likely have to be lower. For example, the Dutch Energy Investment Allowance grants a deduction of 45.5% of investment costs. With enough taxable profit and a corporate tax rate of, for example, 20%, a company's tax savings would therefore be 20% of 45.5%, resulting in a funding rate of 9.1% per motor.

Energy Efficiency Promotion Plan. It is also pertinent to acknowledge that other countries have lower funding rates. For instance, in Austria, the maximum funding rate is 30% of the eligible investment costs.

The policy is set to be applicable to motors in the power class 37 - 75 kW (laying inside the range that was addressed in the Energy Efficiency Promotion Plan (PPEC) in Portugal) and is active from 2025 to 2030 (meaning that the budget is used up during this period). Funded is the early replacement of IE1 and IE2 motors by new IE4 motors. It is further assumed that, as a consequence of the funding schemes, companies will replace motors two years earlier than they would have done in the absence of such policy intervention. The savings resulting from such a replacement are then compared to a base case scenario in which the motor is replaced after reaching the average lifetime, which in this case is two years later. Therefore, savings are generated for a period of two years, unless the replacement is with a superior product to that which is currently the average on the market, in which case the positive effects of more efficient motors would provide savings compared to the base case over the entire lifetime.

It must be emphasised that the provided example is hypothetical. There are very few programmes that deal exclusively with electric motors and the assumptions on lifetime reduction are difficult to estimate. Subchapter 5.4 will highlight some of the key limitations of the example and the impact assessment in general.

A brief explanation of the implementation steps shall be provided at this point.

When opening the Excel file the user has to move from the "Info" tab which comprises background information on the model to the "Dashboard" tab.

On the "Dashboard" the user can adjust the values in the blue shaded fields, with the inputs shown in Table 2.

Table 2 User input in the hypothetical policy example

Geographical scope (EU or Member State)	EU average
One material for impact assessment	Copper
Power class of impacted motors	37 – 75 kW
Programme budget	2 000 000 €
Funding rate per new motor	50%
Timeframe of policy (start and end year)	2025 – 2030
Lifetime reduction (how many years earlier do motors leave the market, respective to their assumed lifetime in the underlying motor market assessment)	2 years
Replacement of efficiency level (more than one class can be selected)	IE1, IE2
Replacement by efficiency level	IE4

While inserting values the user is already provided with the background data for purchase price of an individual motor of the selected power class and efficiency level (in this case an IE4 motor in the range of 37 to 75 kW with an estimated purchase price of 3 317.75€) as well as the purchase price with activated policy (1 658.88€).

Figure 4 shows the implementation steps in the Excel tool.

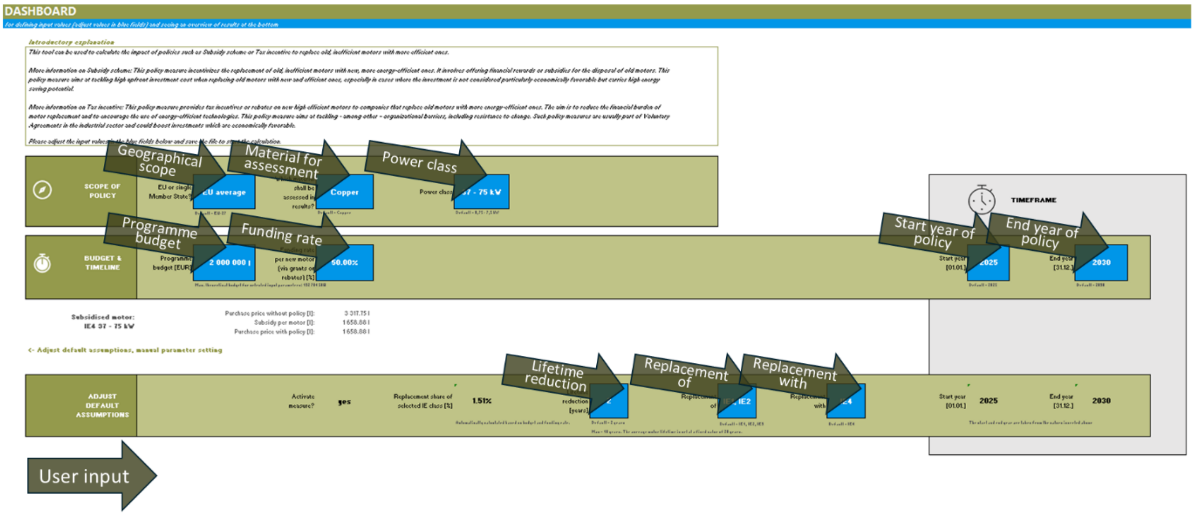

Figure 4 Implementation of theoretical case study in sheet "Dashboard"

5.2.2 Results

After saving the file to refresh the calculation and waiting until the processing is complete, the numerical values quantifying key outcomes are directly provided on tab "Dashboard" where the user has entered the inputs.

It shows results on individual motor level and on stock level, from industry and policy maker perspective and for economical, environmental and material impacts (see Figure 5).

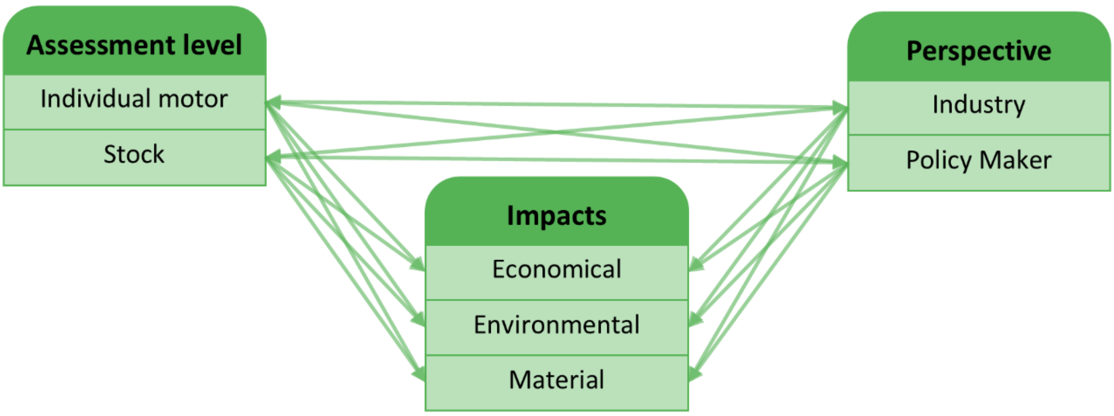

Figure 5 Dimensionality of results

In the following paragraphs the results are displayed grouped into the three levels of impacts.

Economical impacts

On individual motor level (see Figure 6) provided are the yearly savings, years until amortisation and internal rate of return (IRR) for replacing different efficiency classes. Here it has to be noted that the calculation of the IRR is for informational and decision support purposes and shows an IRR over the full lifetime of the motor. It can be understood as the company perspective on an individual motor replacement. In the example it provides the information that replacing an IE1 motor with an IE4 motor leads to yearly electricity cost savings of 673.36€, resulting in 4.93 years until amortization and an IRR of 20%. Similar we can learn about the same figures for other possible configurations such as replacing an IE2 or an IE3 motor. These figures are not limited to the selected efficiency class but instead meant as orientation for policy makers to jump back to the inputs and decide which replacements the policy should address. In addition, the purchase price with and without subsidy of the selected motor are provided. As reported in chapter 4, typical for a subsidy scheme are payback times of more than 3-4 years, while tax incentives in combination with voluntary agreements are often applied to replacements with lower payback times.

on individual motor level (crediting full savings over entire lifetime)

Subsidised motor	IE4 37 - 75 kW
Purchase price without policy [€]	3 317.75 €
Subsidy per motor [€]	1 658.88 €
Purchase price with policy [€]	1 658.88 €

	Replacement of	Replacement with	Yearly savings [€]	Years until amortisation	Internal rate of return (IRR) [%] *assuming 20 years lifetime and residual value = 0€*
without subsidy	IE1	IE4	673.36 €	4.93	20%
	IE2	IE4	412.28 €	8.05	11%
	IE3	IE4	212.59 €	15.61	2%
	IE4				
with subsidy	IE1	IE4	673.36 €	2.46	41%
	IE2	IE4	412.28 €	4.02	25%
	IE3	IE4	212.59 €	7.80	11%
	IE4				

Figure 6 Results on individual motor level

For the results on stock level, we find that the programme results in 1 206 motors being replaced from 2025 to 2030 when the policy is active and resulting in a total energy savings of 34.21 GWh over the modelling time period until 2050 (and savings of 10.35 GWh while the policy is active from 2025 to 2030). The results on stock level are also converted to ktoe for easy usage in policy reporting and are also provided for each individual year from 2000 until 2050.

For industry the programme would result in 5 763 645€ in electricity cost savings and triggered additional investments of 1 673 217€ for purchasing the more efficient and expensive IE4 motors.

The provided hypothetical policy example results in a cost effectiveness of 0.06€ per kWh saved.

Now with the ranges for cost effectiveness of non-financial policies such as information campaigns and capacity building, **EU-M³** can provide orientation for what such policy might cost to achieve similar savings. These numbers are provided at a range of 171 056€ to 513 169€. As discussed earlier, it has to be stressed that these values are to be treated with caution and only indicatively since they are based on individual country examples without information on the design, scope and budget that led to the reported savings. While such programmes on small scale might be cost-effective, their scalability will be very much case specific.

Environmental impacts

The total energy savings of 34.21 GWh lead to GHG savings of 12.14 thousand tonnes CO_{2eq}.

On a separate tab in the Excel "Graphical Results" the results are visually displayed. The user finds a variety of information, e.g. on motor sales and stock in the selected geographical scope or on the selected materials (entering, exiting and on the market in a given year). Also graphs are provided on environmental and economic impacts of the policy.

Figure 7 shows such graphical results for energy and GHG savings over the modelling timeframe, and Figure 8 presents additional explanations on the underlying logic and its influence on the energy savings. As can be seen in Figure 7 the two curves run in parallel as GHG savings are derived from energy consumption via emission factors of the electricity mix. Savings are generated once the policy becomes active - motors are replaced with higher efficient ones from 2025 to 2030 (compared to a base case of no policy intervention). From 2030 no more additional replacements are taking place, but the more efficient motors on the market keep delivering savings. Since motors are only replaced two years before their normal end-of-life, a flattening of the curve can be seen from 2027. There is the first reduction of savings noticable from 2030 to 2032, when no more (additional) motor replacements are happening but those motors which were not impacted by the policy become replaced (by market average). From 2033 to 2044 there is an equilibrium, with motors still generating savings. Finally, from 2045, replaced motors start exiting the market and energy consumption and impacts once again equalise with the base case.

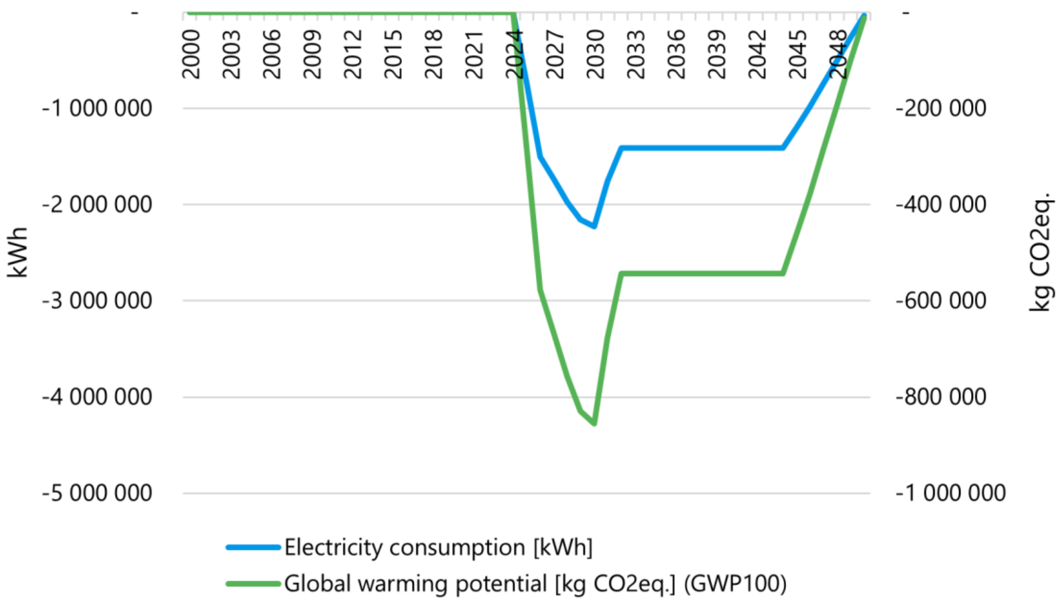

Figure 7 Example graphical results: environmental impact savings by early motor replacement

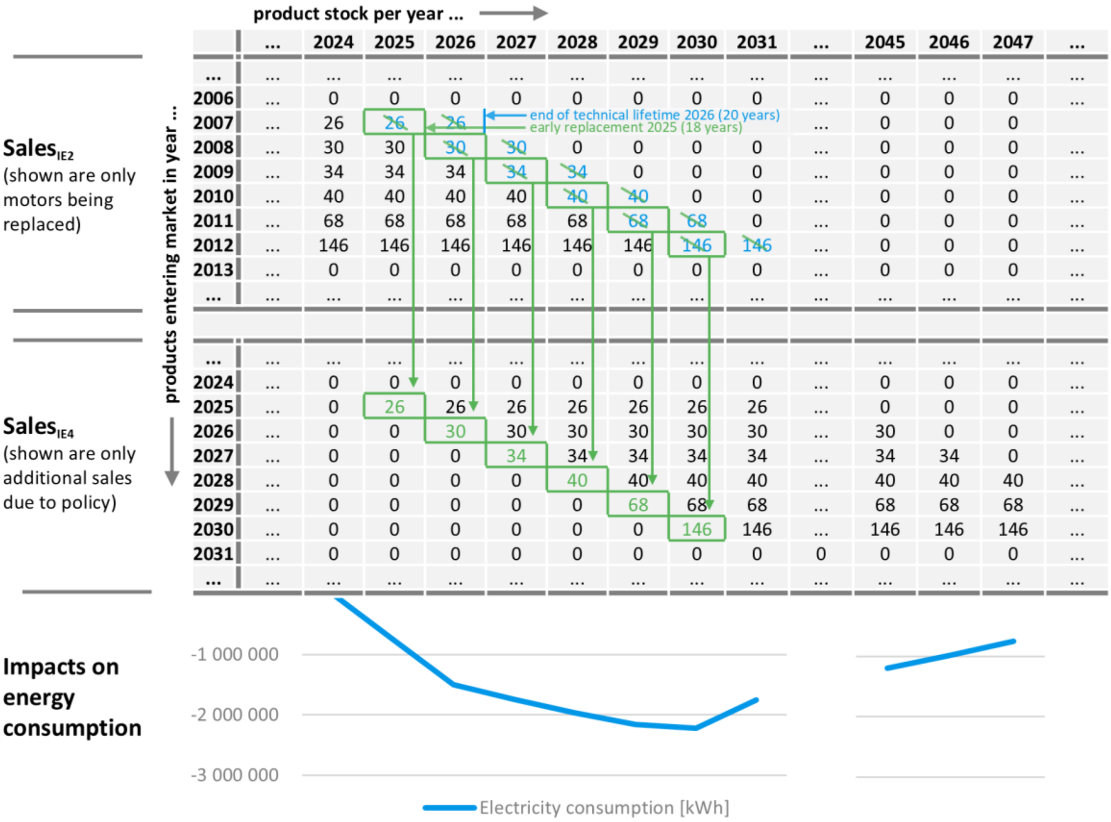

Figure 8 Explanatory representation of sales, stocks, and savings (replacements of IE3 motors are not shown but follow the same logic)

Material impacts

By early replacement with IE4 motors which have a higher usage of Copper the demand for the material on market level is increased by in total 26.02 tonnes. This number is once again accumulated for the years until 2050 and expressed as the difference against a base case with no policy intervention.

Figure 9 shows the results on stock level as they are displayed on the Dashboard in the model.

on stock level (1950-2050, compared to a base case with no replacement/ repair)		
impacted motors		
Number of replaced motors		1 206
results for policy maker		
Programme budget [EUR]		2 000 000 €
Energy consumption [kWh]	-	34 211 246
Energy consumption [ktoe]	-	2.94
Programme efficiency [EUR / kWh saved]		0.06
Environmental impact [kg CO2eq.]	-	13 143 251
Copper demand [kg]		26 018
results for industry / end-user		
Electricity costs to industry / end-user [EUR]		-5 763 645
Investment costs to industry / end-user [EUR]		1 673 217
Total cost savings [EUR]		-4 090 428

Figure 9 Results on stock level

The model provides indications of the maximum size of the programme budget for the selected geographical scope, power class, funding rate, programme duration, lifetime reduction and efficiency classes. In this case study, the 2 000 000€ programme budget represent a 1.51% share of all possible IE1 and IE2 motors available for replacement from 2025 to 2030. This results in a maximum theoretical budget of 132 784 586€, maximum energy savings of 2 271.36 GWh and environmental savings of 872.61 thousand tonnes kg CO_{2eq}.

5.3 Examination of existing policies

5.3.1 Introduction and user inputs

To approximate the impacts of existing or past policies, a few of the listed programmes in chapter 4 shall be assessed. However, it has to be noted that the available data on the programmes is limited, requiring certain assumptions to be taken.

The following programmes are chosen for assessment: the Portuguese Energy Efficiency Promotion Plan (PPEC) and the Swiss ProKilowatt programme as representatives of subsidy schemes, and the Dutch Energy Investment Allowance as an example of a tax incentive. The Portuguese programme, about which the most information is available, is discussed in the most detail, while the findings are also applicable to a certain extent to the other programmes.

Details on the programmes, available data and required assumptions is provided hereafter, before results are discussed in subchapter 5.3.2.

Energy Efficiency Promotion Plan (Portugal)

Data is provided for the 6th edition of the programme, spanning from 2017-2018. The programme included measures to promote the installation of High Efficiency Motors (IE3 or IE4) within the 0,75 kW to 400 kW power range (in the manufacturing, agricultural and fisheries sectors) as a replacement for low efficiency motors (motors of efficiency class below IE1). A financial incentive of 51.1% of the average new motor price (including installation costs) was provided with a total budget of 896 767€. The measure also foresees a rapid assessment of the use profile and load of the motor to ensure a correct dimensioning of the replacement motor.

To model such policy with limited input data several assumptions have to be taken.

The background data from the market analysis does not include IE0 motors. Therefore, either the user would have to insert his own data on the motor stock *(sheet “2_StockToSales” blue shaded area named “MANUAL OVERRIDE”)* or work with the given data by making the assumption that IE1 motors are replaced instead. Here the assumption is followed that IE1 motors are replaced. This is evidently a conservative assumption, since the energy efficiency of IE0 motors will be significantly lower compared to that of IE1 motors. Since it is not clear what the share of different efficiency classes of replacement is and to prevent the gradient of performance between old and new motors from becoming even smaller, motors are assumed to be replaced with the more efficient IE4 motors (compared to IE3 motors). Following the same logic the lifetime reduction is set to 5 years (IE1 motors leave the market 5 years earlier than their normal lifetime, i.e. after 15 years lifetime). The given power range of 0.75 kW to 400 kW power range equals all the power classes in our model. The most intricate approach would therefore be to differentiate into the different power ranges, conduct a calculation for each and sum up the results. However, due to the lack of available data on distribution between power ranges, the medium range of 37 – 75 kW was selected to represent an average size in terms of power consumption and investment costs.

The assumptions demonstrate that available data are crucial and often not available. Also, it becomes clear that many nuances (such as exclusion of specific sectors, coverage of installation cost or dimensioning of motors) are difficult to accurately represent. The input data can be seen in Table 3.

Table 3 User input for policy assessment 1

Geographical scope (EU or Member State)	Portugal
One material for impact assessment	Copper
Power class of impacted motors	37 – 75 kW
Programme budget	896 767€
Funding rate per new motor	51.10%
Timeframe of policy (start and end year)	2017 - 2018
Lifetime reduction (how many years earlier do motors leave the market, respective to their assumed lifetime in the underlying motor market assessment)	5 years
Replacement of efficiency level (more than one class can be selected)	IE1
Replacement by efficiency level	IE4

ProKilowatt (Switzerland)

Information on the Swiss programme is less detailed, particularly on the role of motors within the programme. It is mentioned that only projects with a payback time of more than 4 years are eligible for funding, and that motor systems accounted for 29% of the total investments of the program.

During the period 2010-2023, the program has funded 956 projects providing 430 000 000€ in public spending. With the 29% share this results in 124 700 000€ programme budget dedicated to motors.

Prokilowatt offers a maximum subsidy of 30% of the investment cost.

Due to the limited data on motor replacement, missing information is approximated. The model only includes country scaling factors for EU-27 countries, therefore Sweden is taken as an approximation as a country with a comparable energy consumption. Further assumptions on missing data can be found in Table 4.

Table 4 User input for policy assessment 2

Geographical scope (EU or Member State)	Sweden (as approximation for Switzerland)
One material for impact assessment	Copper
Power class of impacted motors	7.5 – 37 kW
Programme budget	124 700 000€
Funding rate per new motor	30%
Timeframe of policy (start and end year)	2010 - 2023
Lifetime reduction (how many years earlier do motors leave the market, respective to their assumed lifetime in the underlying motor market assessment)	2
Replacement of efficiency level (more than one class can be selected)	IE1
Replacement by efficiency level	IE3

Dutch Energy Investment Allowance (Netherlands)

As an example of a tax incentive the Dutch programme serves as an example. Similar to the Swiss programme, the available data from chapter 4 is limited.

The minimum amount of funding per company is reported as 2 500€ with a maximum investment amount of 136 000 000€. Companies can deduct 45.5% of the investment costs from the taxable profit. With enough taxable profit and a corporate tax rate of, approximately 20%, a company's tax savings will therefore be 20% of 45.5%, resulting in a funding rate of 9.1% per motor. Different electric motors are eligible for funding, including inter alia those with a nominal power of less than 75 kW. In 2023 the budget is 249 000 000€, but it is unclear how much of this budget will be devoted to motor replacements – in light of a lack of data a share of 1% is assumed for the power class of 0.75 – 7,5 kW, representing only fraction of the overall motor market. Therefore, several assumptions have to be taken, which can be seen in Table 5.

Table 5 User input for policy assessment 3

Geographical scope (EU or Member State)	Netherlands
One material for impact assessment	Copper
Power class of impacted motors	0.75 – 7.5 kW
Programme budget	2 490 000€
Funding rate per new motor	9.1%
Timeframe of policy (start and end year)	2023
Lifetime reduction (how many years earlier do motors leave the market, respective to their assumed lifetime in the underlying motor market assessment)	2
Replacement of efficiency level (more than one class can be selected)	IE1
Replacement by efficiency level	IE4

5.3.2 Results and validation

Energy Efficiency Promotion Plan (Portugal)

The programme which was meant to resemble the Portuguese Energy Efficiency Promotion Plan with a programme budget of 896 767€ and a funding rate of 51.10% results in 529 motors being replaced. This number is 26% higher then the 420 replaced motors reported from the scheme. This will likely be due to the fact that it is not clear which motor sizes have been exchanged under the scheme, nor their purchase price and how strongly its average diverges from the numbers of the motor market study underlying the model (in this case 3 318€ for an average IE4 motor in the range 37 – 75 kW).

According to the model the 529 IE1 motors in the power range of 37 – 75 kW that have been replaced represent 4.78% of the overall replaceable IE1 37 – 75 kW motors from 2017 to 2018 (based on the underlying inventory data and the country scaling). Here it has to be noted that for the overall number of motors the model uses a country scaling reducing the EU numbers based on Member State gross electricity. While this can serve as an approximation for industry size and correspondingly number of motors, it might be over- or understimating the factual numbers.

Regarding economical impacts of an individual motor exchange, the exchange of an IE1 with an IE4 motor results in an IRR of 16% or 5.93 years until amortization. This number seems adequate for subsidy schemes (which should be preferably support investments with a payback time of more than 3-4 years, see subchapter 4.2.1). Economic impacts of the overall programme for the modelling timeframe until 2050 are calculated to triggering company investments of additional 249 147€ for new motors, while evoking energy cost savings of 3 131 171€ (or an overall net benefit of 2 882 024€). The energy cost savings are resulting from a reduction of energy consumption by 22.36 GWh. These savings are significant, however considerably lower than the 115 GWh reported by the scheme (even achieved with a lower number of replaced motors). When analysing potential reasons for this diversion, again it has to be pointed to missing data and required assumptions. Particularly, the following relevant data of the programme was missing:

- period of impact assessment,
- share of power ranges (of replaced motors and replacement motors),
- share of efficiency class (of replaced motors and replacement motors),
- average energy consumption of replaced motors,
- average lifetime of replaced motors.

Particularly the necessary assumption that not IE0, but IE1 motors have been replaced, and that these motors in the model were replaced after only 15 years lifetime will likely have led to a strong underestimation of potential savings. If imagining a motor of e.g. 30 years lifetime the efficiency gains by replacement will be significantly greater.

Regarding environmental impacts the savings calculated in the model accumulate to 8.59 thousand tonnes CO_{2eq}. As could be expected (and in conformity with the lower energy savings compared to the reported numbers of the Portuguese Energy Efficiency Promotion Plan) this number is much lower than the 43 thousand tonnes CO_{2eq} reported by the scheme. Consequently, also the cost-effectiveness ratio with 0.04€/kWh saved is higher than the 0.008€/kWh reported by the scheme.

Regarding material savings, the model calculates an additional 4.91 tonnes of Copper necessary to meet the increased demand of the higher efficiency and more material intensive IE4 motors. This impact is measured over the modelling timeframe until 2050 and for the entire Portuguese market.

Overall, the results show significant savings that might be achieved by implementing such programme. However, it also shows great variation from the reported figures of the actual scheme, pointing to challenges or limitations when estimating the impact of existing programmes due to a lack of data availability and necessary modelling simplification. It is important to underline that these variations do not directly imply inaccuracies in the reported programme savings or the modelling methodology used in this study. Rather, one is essentially comparing two different programmes under the provided assumptions and parameters. To bridge the identified gaps and achieve a closer match between the model results and the actual outcomes of the scheme, a more detailed set of data would be required. This should not detract from the value and insights provided by both the model and the programme, but rather highlights the inherent complexities and uncertainties in projecting and assessing the impacts of such measures.

ProKilowatt (Switzerland)

The results for the Swiss programme result in 4.02 TWh of saved energy, compared to the official numbers of 3.2 TWh reported by the Swiss programme. The energy savings results in environmental impact savings of 1 542 thousand tonnes CO_{2eq}. The calculated numbers results in a programme efficiency of 0.03€/kWh, matching the 0.03€ of public subsidy per kWh saved over the lifetime of equipment reported by the Swiss programme.

Dutch Energy Investment Allowance (Netherlands)

With a budget of 2 490 000€ the model results in energy savings of 337.77 GWh and environmental savings of 129.77 thousand tonnes CO_{2eq}. This results in programme efficiency of 0.01€/kWh saved which can be converted to 0.019€/kg CO_{2eq} saved. The latter number is in the order of magnitude of the 0.014€/kg CO_{2eq} saved reported by the Dutch scheme.

As an additional output, the model estimates an additional 91.58 tonnes of Copper demand. All numbers provided are calculated for the modelling timeframe until 2050.

5.4 Discussion

The following paragraphs use the examples provided above to highlight some of the limitations of the modelling.

The reliability of the results is dependent on the quality of user inputs as well as on the background data. Underlying data sources have been reported in Table 1, nonetheless the level of reliability varies and some simplifications had to be taken. For example, in the motor system analysis the lifetime had been set to a **static value of 20 years** for all motors to match the actual motor data. In reality there will be a distribution function which would lead to motors staying in the market much longer. In absence of any reliable data on this the model was designed in a way to work with a fixed lifetime representing the average lifetime of motors on the market. In terms of the results this could mean that our figures are rather conservative as in reality most savings would be achieved by replacing the oldest and most inefficient motors from the market. Such motors are underrepresented in our analysis.

The calculated cost efficiencies are mostly in an order of magnitude as those reported in the identified policy examples in chapter 4. The Portugal Energy Efficiency Promotion Plan (PPEC) reported a cost-effectiveness ratio of 0.008€ / kWh saved over the lifetime of the equipment, and the ProkiloWatt programme in Switzerland achieved a cost-effectiveness ratio of 0.03€ of public subsidy per kWh saved over the lifetime of equipment.

The **EU-M³** is limited to apply the policy to one selected power class per calculation. Furthermore, there is a tradeoff between accuracy of the calculation and complexity. The **EU-M³** calculates bottom up all motors on the market with a high level of dimensionality and without the use of programme language such as VBA. Due to the complexity each calculation requires waiting time and can impede the usability. In return for the complexity the model represents the market dynamics with a high level of granularity, tracing motors entering, being on and exiting the market, including their material composition, energy consumption and environmental impact.

Due to the characteristics of each policy, it was decided to only calculate the effect of financial policies based on programme budget as well as other stated assumptions by the user (compared to other policy types). For information campaigns and capacity building it is even more difficult to estimate assumptions on the number of replaced motors. To nonetheless provide an orientation for other policy types without feigning accuracy or reliability as a calculated number which is heavily based on underlying assumptions would do, it was decided to use the cost effectiveness ranges from existing policies to provide ranges of what an information campaign might cost to achieve similar savings. It has to be stressed here that due to the design, scope and budget that led to the reported savings the numbers can vary immensely from the example under consideration. Some other limitations shall be mentioned briefly. The country scaling is based on gross electricity production as a rough proxy for industry size with clear limitations in accuracy. The assumptions on lifetime reduction (as a default assumption two years) might be difficult to determine for policy makers but are an essential input value – therefore it was decided to place them as default assumption and require users to open hidden cells in the Excel to make changes. This way only the experienced user will make changes.

In summary, the **EU-M³** model provides useful insights but its results depend heavily on the quality of inputs and underlying data. While it offers a detailed view of market dynamics, its estimates should be interpreted with caution due to the necessary simplifications and assumptions inherent in the model.

6. Summary & conclusion

The EU-MORE project, through the development of the **EU-M³**, has made significant strides towards understanding and improving energy efficiency in the European motor market. The model, developed through a rigorous five-step methodology, serves as a comprehensive tool for analyzing the impact of existing and emerging policies on electric motors.

Three policies were selected for impact assessment inside the model at different levels of granularity: financial policies such as scrappage scheme and tax incentive in combination with voluntary agreements can be calculated bottom-up, deriving impacts on the basis of effects on the total motor market over the modelling timeframe. For information campaigns and capacity building, cost-effectiveness factors from existing schemes were used to provide indicative figures on how such a scheme could possibly compare to a scrappage scheme, with all the limitations such approach entails. A case study of a hypothetical policy and on existing policies was conducted to assess the potential for reducing energy demand and greenhouse gas emissions. The results of the model indicate that these policies can make a significant contribution to energy efficiency and GHG reduction.

However, the model has limitations. The reliability of the results is highly dependent on the quality of user inputs and some simplifications had to be made due to the complexity of the calculations. Despite these limitations, the **EU-M³** provides valuable insights and a transparent projection of European policy impacts.

In conclusion, the **EU-M³** can be an effective tool for policymakers and stakeholders, enabling a better understanding of the impact of motor-related policies, which will help them to develop policies fostering the motor market transformation. Though it has its limitations, it offers substantial value in developing strategies for improving energy efficiency in the European motor market. The application of the model to selected policies demonstrates its potential to provide sound projections of policy impacts on energy demand and GHG emissions. With further refinement and expansion, the **EU-M³** could play a vital role in shaping energy efficiency policies in the future.

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