EU-MORE

EUropean MOtor REnovation initiative

Estimating savings

The EU-MORE model for evaluating electric motor replacement policies

3rd December 2024, Dr. Robin Barkhausen (Fraunhofer ISI)

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

Electric motors

Electric motors > 50% of EU electricity consumption

→ High impact in energy consumption & environmental impacts

A total of 8 billion motors in EU

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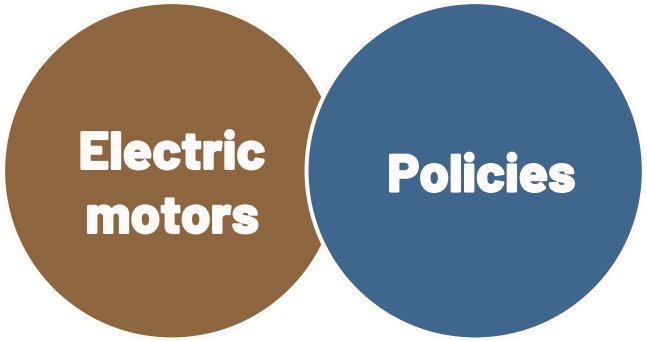

Ecodesign Directive
(Minimum Energy Performance Standards)

Financial policies
(subsidy schemes or tax rebates)

Non-financial policies
(information campaigns and capacity building)

- Motor policies with goal to reduce significant environmental impacts
- Focus on use phase, energy & CO_2

EU-MORE model for evaluating replacement policies

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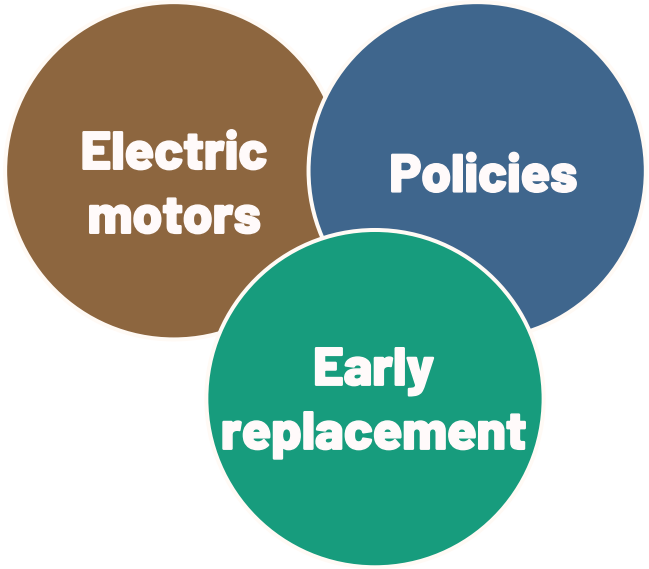

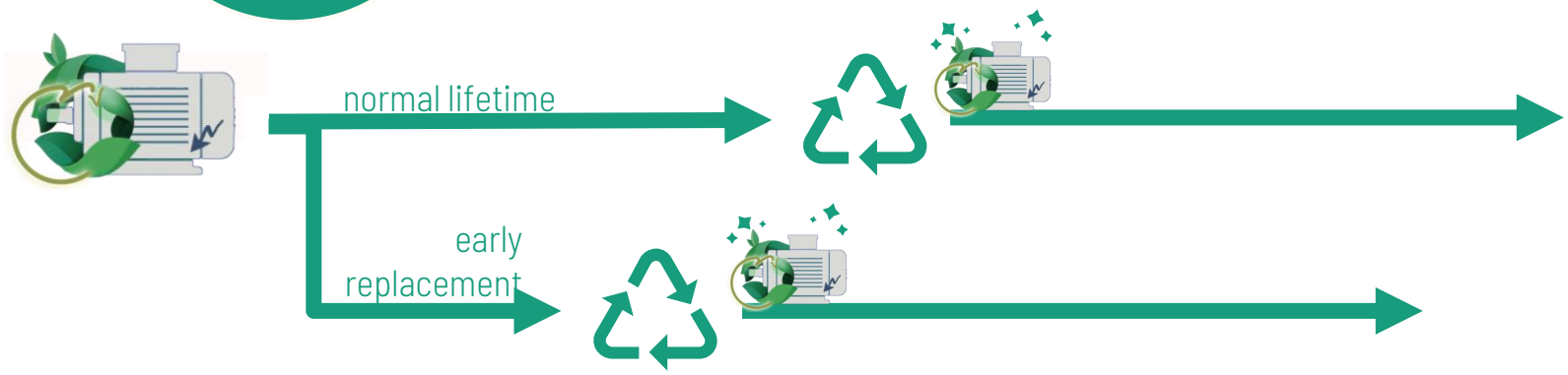

EU-MORE model for evaluating replacement policies

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EU-MORE Activities

Background

- Assessment of motor market
- Policy review
- Analysis of efficiency trends
- Analysis of end-of-life practice

New policy development

- Co-creation workshops at member-state level
- EU-MORE Knowledge Exchange Platform
- Tools for impact projection and monitoring
- Align policies with the circular economy

EU-MORE model for evaluating replacement policies

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EU-MORE Partners

EU-MORE

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International Copper Association Europe

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INSTITUTE FOR EUROPEAN ENERGY AND CLIMATE POLICY

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EU-MORE model for evaluating replacement policies

Agenda

Genesis provides insight into the motivation and requirements behind the development of the model, elucidating its evolution and functionality.

Exploration serves as a guide to get started with and how to use the tool, outlining the calculation of policy impacts.

Application presents theoretical and practical country-specific case studies.

Reflection discusses prerequisites and limitations of the model and provides an outlook.

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1. Genesis

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1.1 Motivation & scope

- The EU-M^3 tool is designed to analyze the impact of existing and new policies on electric motor replacement
- The tool was created to help stakeholders and policy makers understand the implications of motor policy decisions

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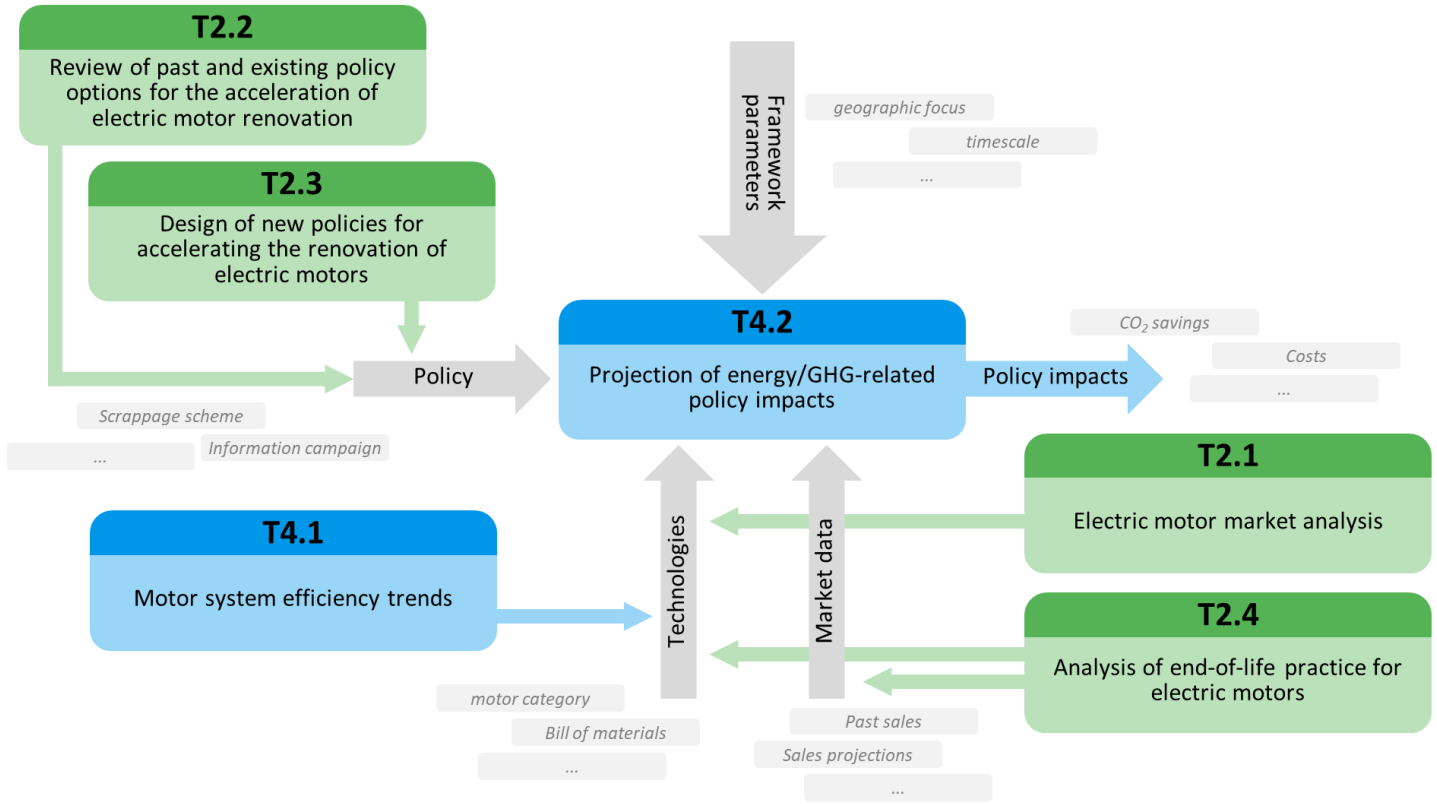
1.1 Motivation & scope

- Scope of tool largely determined by Task 4.2 of the EU-MORE project and preceding tasks including electric motor market analysis, end-of-life practices assessment, motor system efficiency trends review, past and existing policy options, and new policy designs



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1.1 Motivation & scope

- The EU-M^3 tool is applicable to the EU-27 market for industrial electric motors, providing data on motor sales by technology, power range, and efficiency class
- The tool categorizes motors 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 squirrel cage induction motors (SCIM), while IE5 motors represent synchronous reluctance motors (SynRM).
- The EU-M^3 tool currently does not support the use of Variable Speed Drives (VSDs) due to a lack of reliable data on their effects

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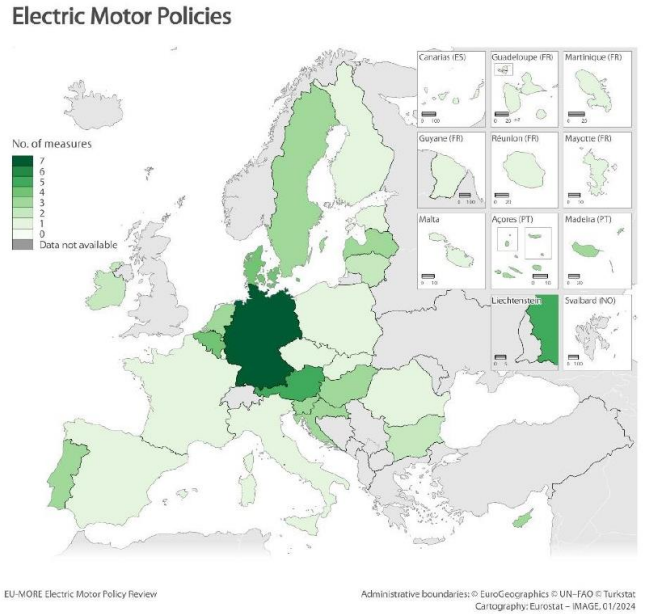
1.2 Covered policies

- Policies for EU-M^3 chosen based on comprehensive review of past and current electric motor policies in the EU (D2.2)
- Selected policies primarily financial, encouraging the replacement of old motors with more efficient ones, but non-financial policies are also considered



Subsidy Scheme

- financial policy incentivizing the replacement of old, inefficient motors with new, energy-efficient ones. For example:
  - Energy Efficiency Promotion Plan (PPEC) (Portugal),
  - ProkiloWatt (Switzerland),
  - National Motor Replacement Program (India)

Tax Incentive in combination with Voluntary Agreements

- financial policy offering tax rebates to companies that replace old motors with energy-efficient ones.

For example:

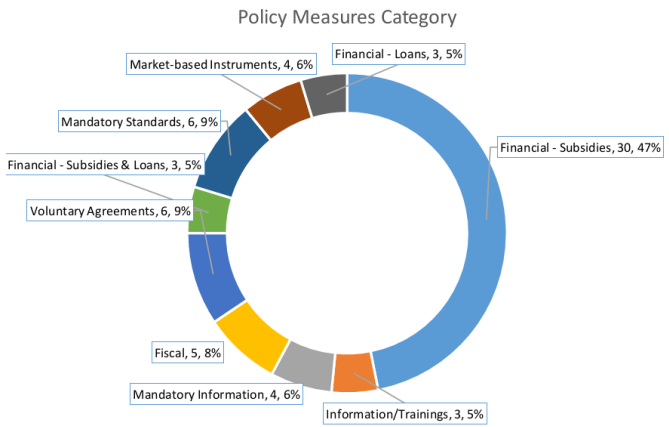
- e.g. Energy Investment Allowance (The Netherlands)
- Energy Investment Allowance (The Netherlands)
- PFE – Program for energy efficiency (Sweden)

Information Campaigns and Capacity Building

- non-financial policies aimed at overcoming informational and behavioral barriers to motor replacement and system optimization

For example:

- e.g. Klimaaktiv (Austria),
- OekoBusiness Vienna (Austria)



D2.2 Review of past and existing policies for the acceleration of electric motor renovation
Faassen, E.; Eichhammer, W.; Sangiorgio, I. (2024)

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1.2 Covered policies

- Financial policies like subsidy schemes and tax incentives are key for impact estimation, differing in the delivery of financial support
- Non-financial initiatives like informational campaigns enhance other policies or instigate behavioural changes, with their impact assessed indirectly through cost-effectiveness ratios from existing programs

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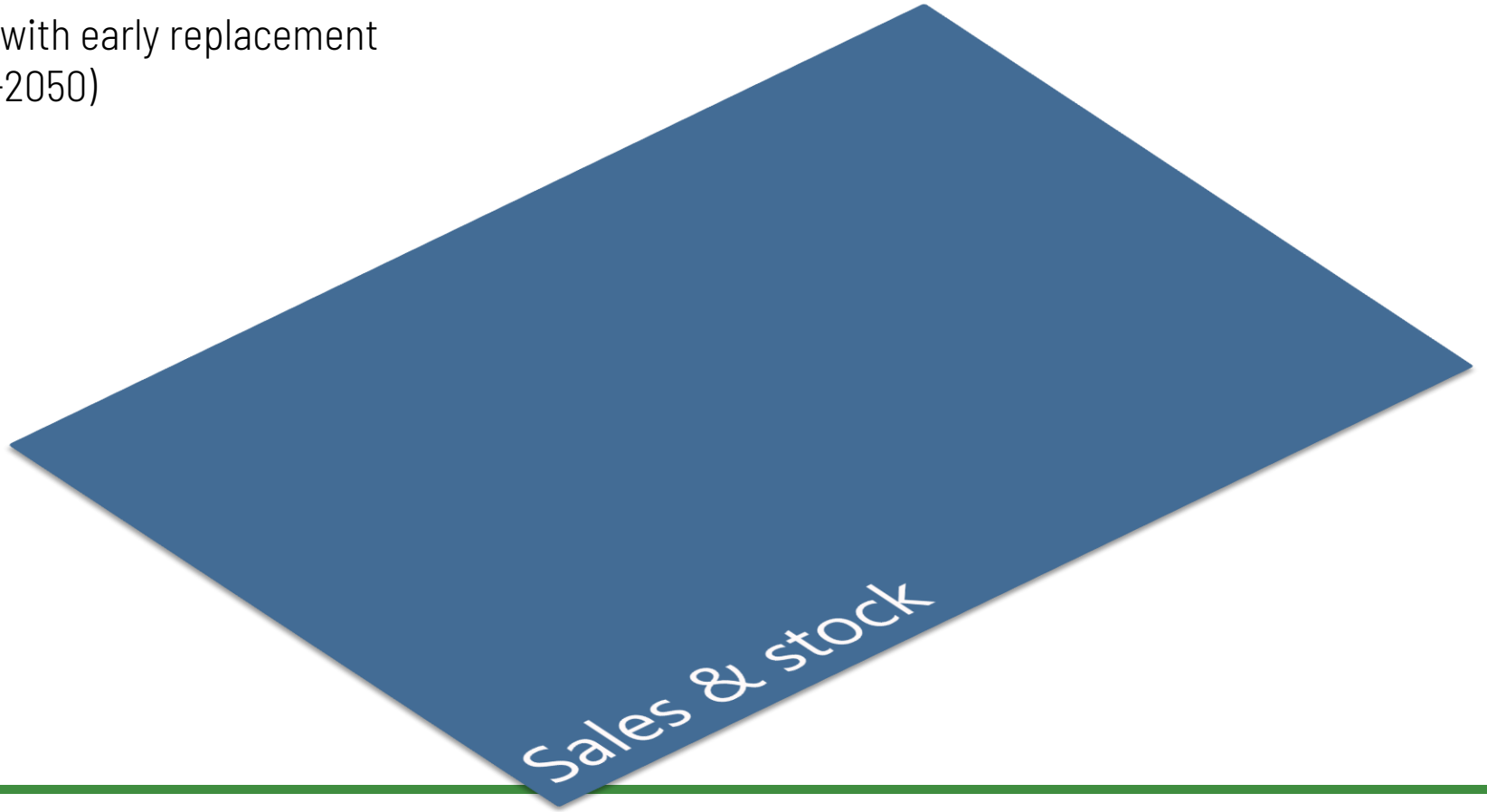
1.3 Underlying logic

- 7 motor efficiency classes
- 2 lifetime scenarios: base cases vs. policy scenario with early replacement
- 100 years (1950-2050)



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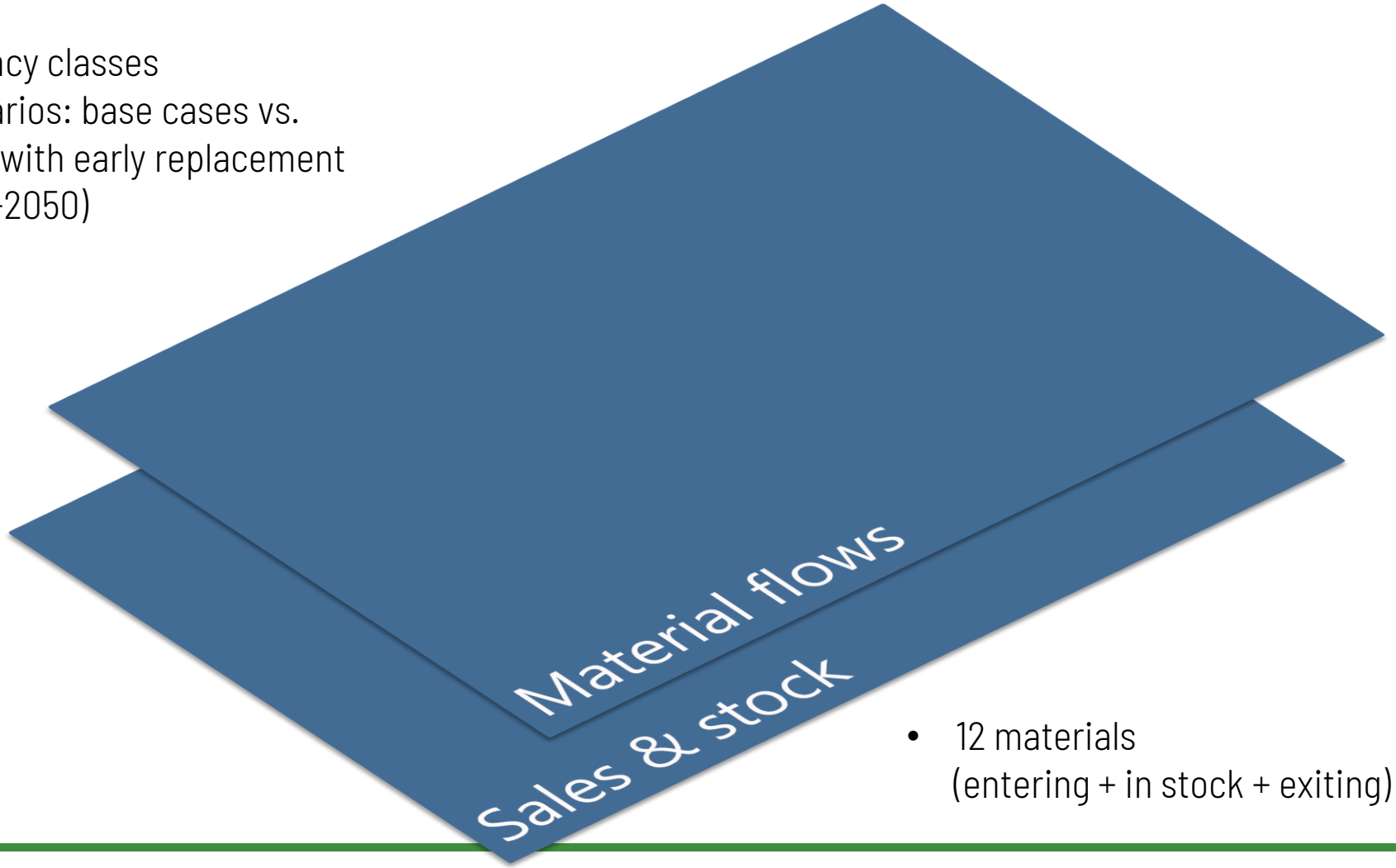

- 12 materials (entering + in stock + exiting)

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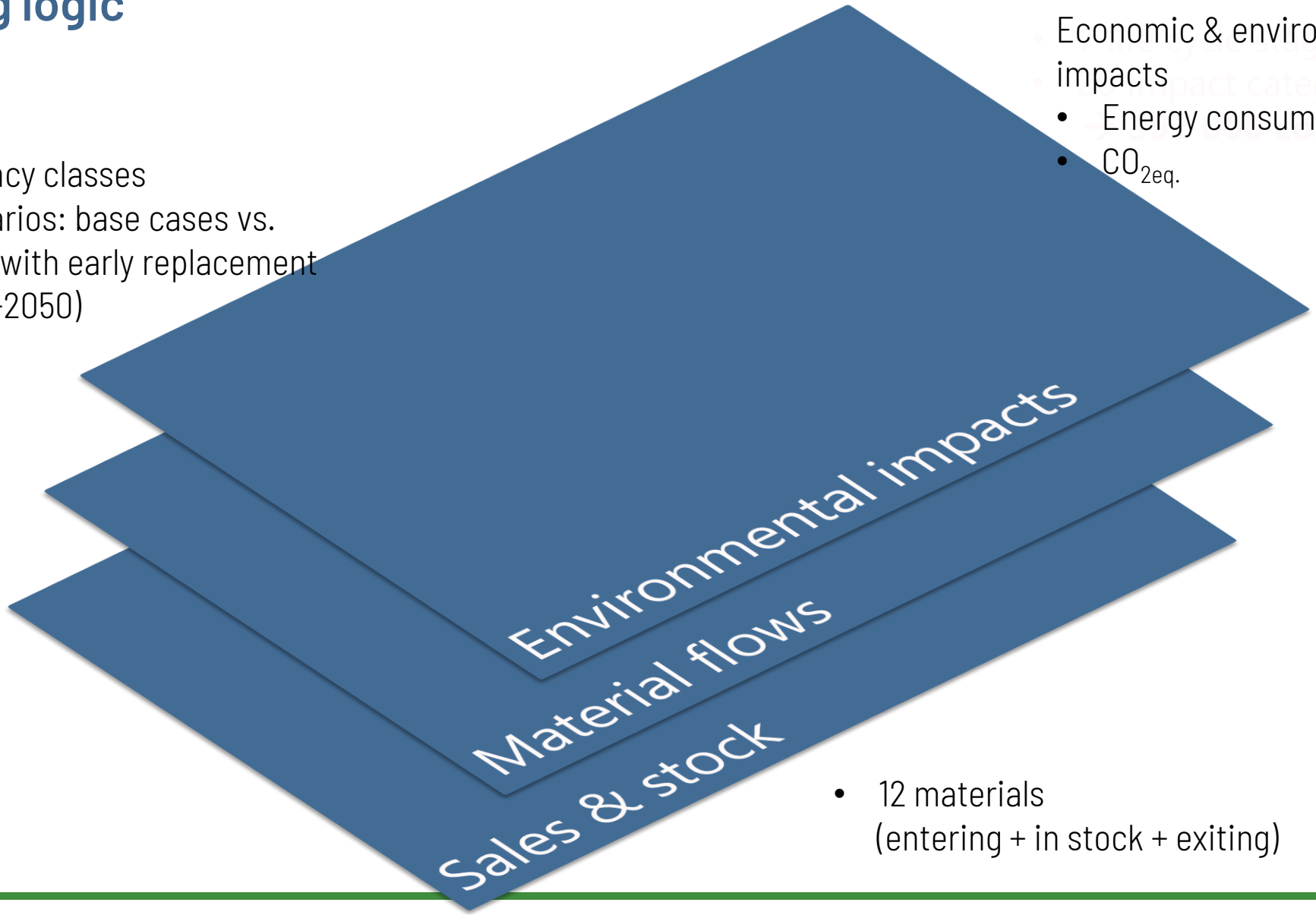

Economic & environmental impacts

- Energy consumption
- $CO_{2eq.}$

- 12 materials (entering + in stock + exiting)

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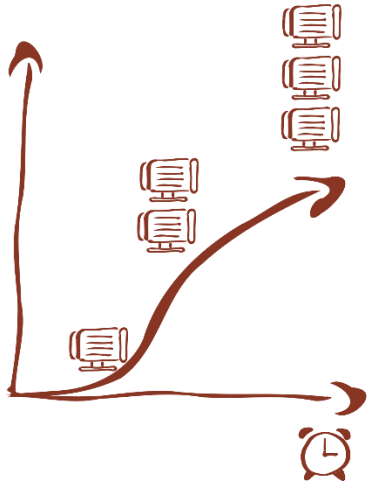
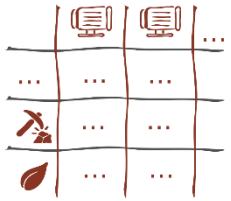
Stock model	Product database	Environmental assessment
		

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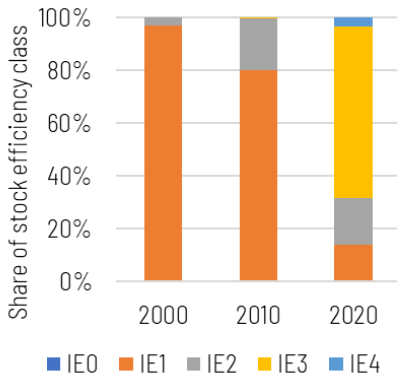
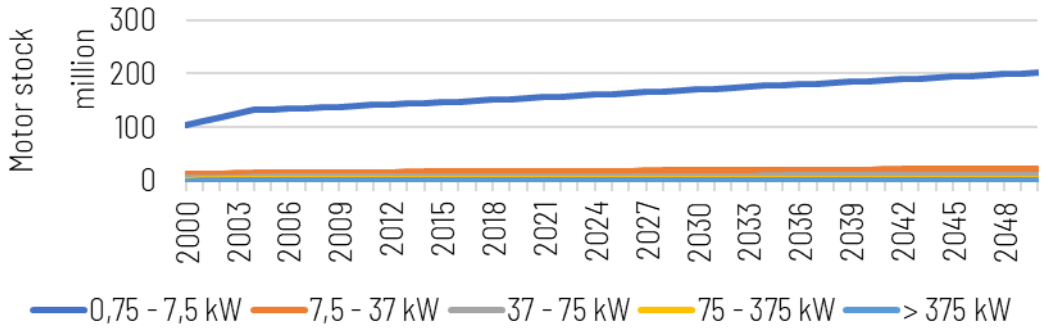
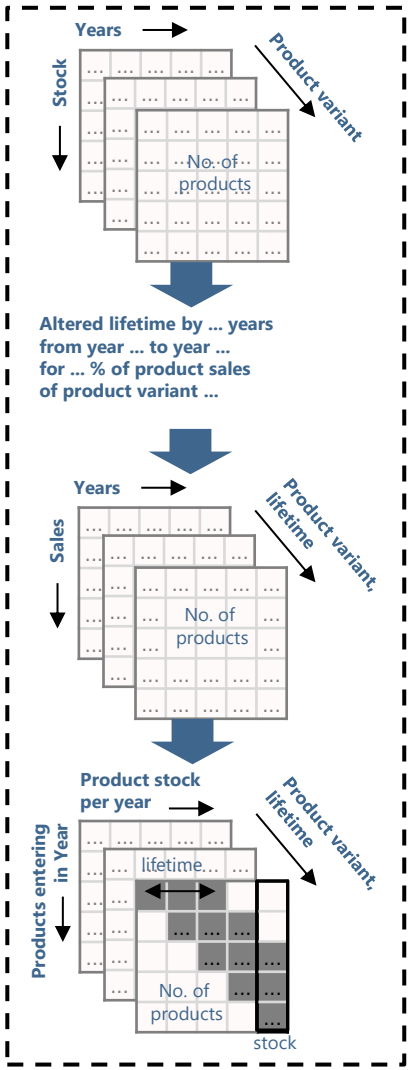
1.3 Underlying logic

Stock model

- exogenously given stock (demand/stock-driven)
- endogenously calculated inflows & outflows







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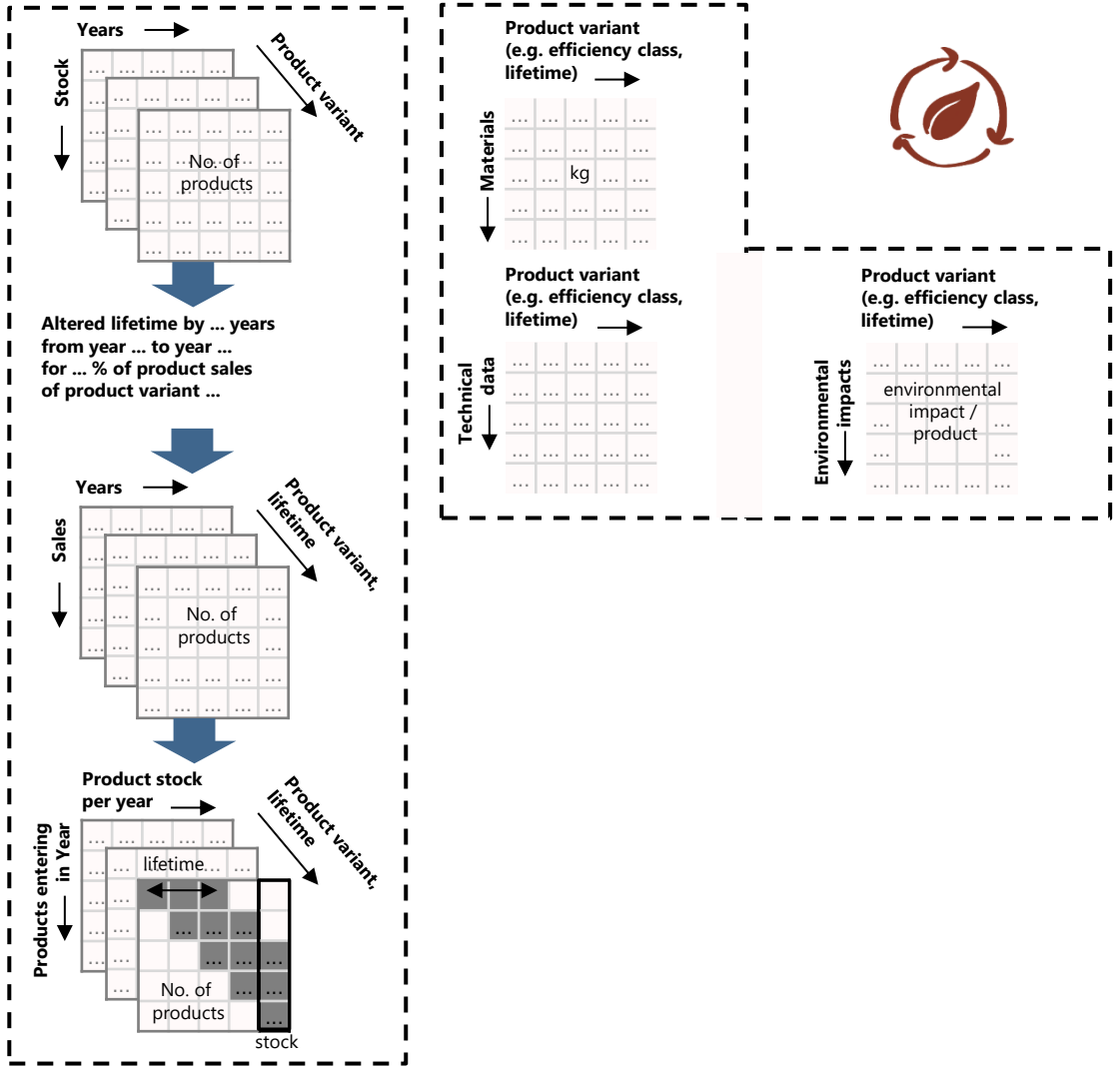
Product database

- interconnector between stock model & environmental assessment
- defines material intensities and other characteristics (energy consumption, efficiency, etc.) of product variants

referring to power class ->	0.75 - 7.5 kW IE0
ARCHETYPES	1.1
Type	SCIM
Power [kW]	3
Efficiency class	IE0
Efficiency [%]	77.8%
Operating time [yearly hours]	3 500
Load factor [%]	60%
	normal
Lifetime	20
CALCULATED CONSUMPTION / LOSSES	
Losses per hour [kWh]	0.51
Total losses over product life [kWh]	35 954
Consumption per hour [kWh]	2.31
Consumption per product year [kWh]	8 098
Consumption over product life [kWh]	161 954
ECONOMIC INPUTS	
Product price [Euro]	189
Electricity rate [Euro/kWh]	0.1685
Electricity cost per year [Euro]	1 364
ENVIRONMENTAL INPUTS	
kg CO2eq. [GWP100] per product year (only use phase)	3 110.96
kg CO2eq. [GWP100] over product life (only use phase)	62 219.26
MATERIALS [kg/motor]	
Aluminium	1.24
Cast iron	7.90
Copper	3.02
Electrical steel	13.84
Impregnation resin	0.00
Insulation material	0.00
Other steel	3.37
Packaging material	0.00
Paint	0.00
Permanent magnets	0.00
-	0.00
-	0.00
Total	29.36



EU-MORE model for evaluating replacement policies

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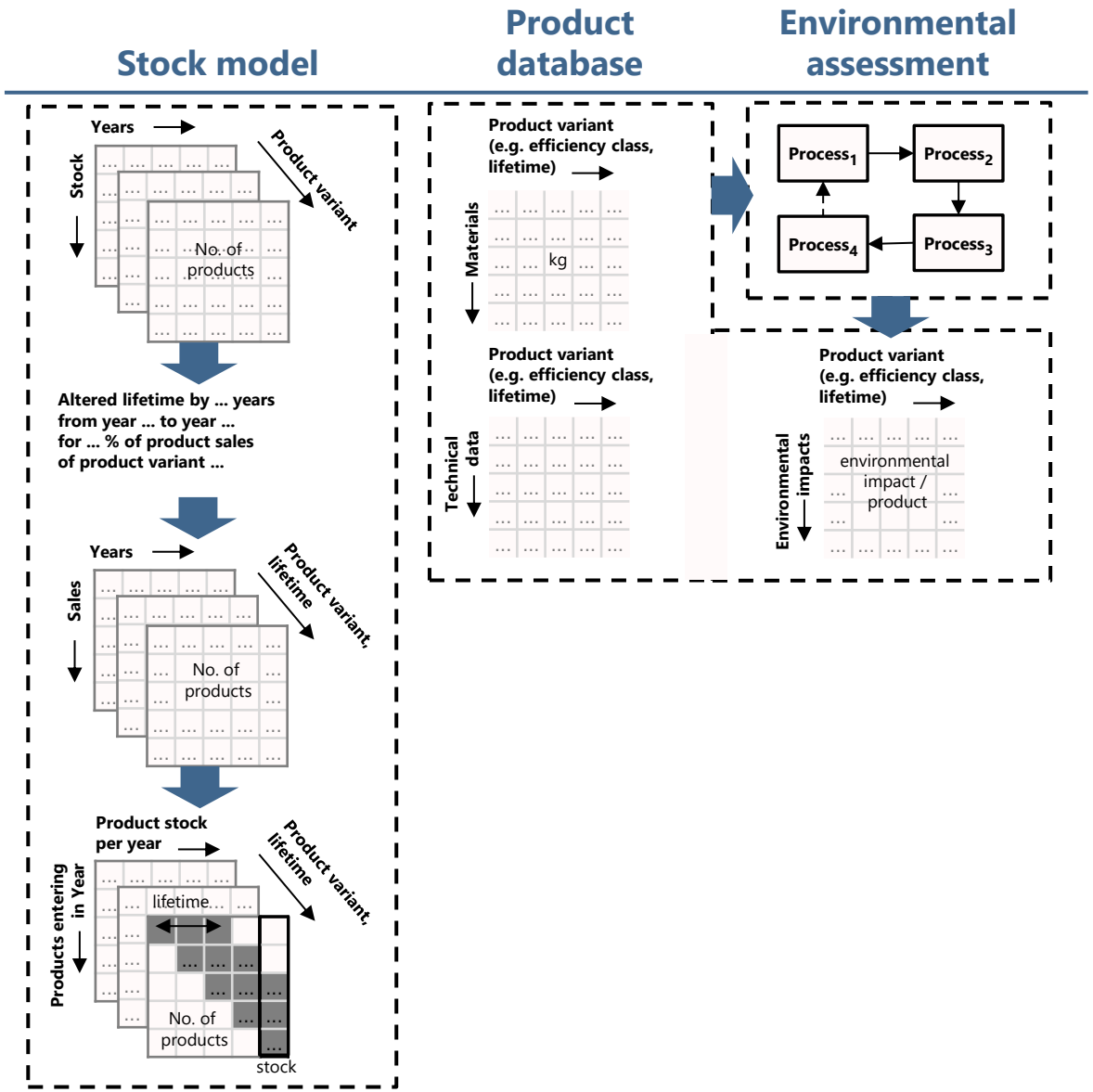
Environmental assessment

- via emission factors of the electricity mix



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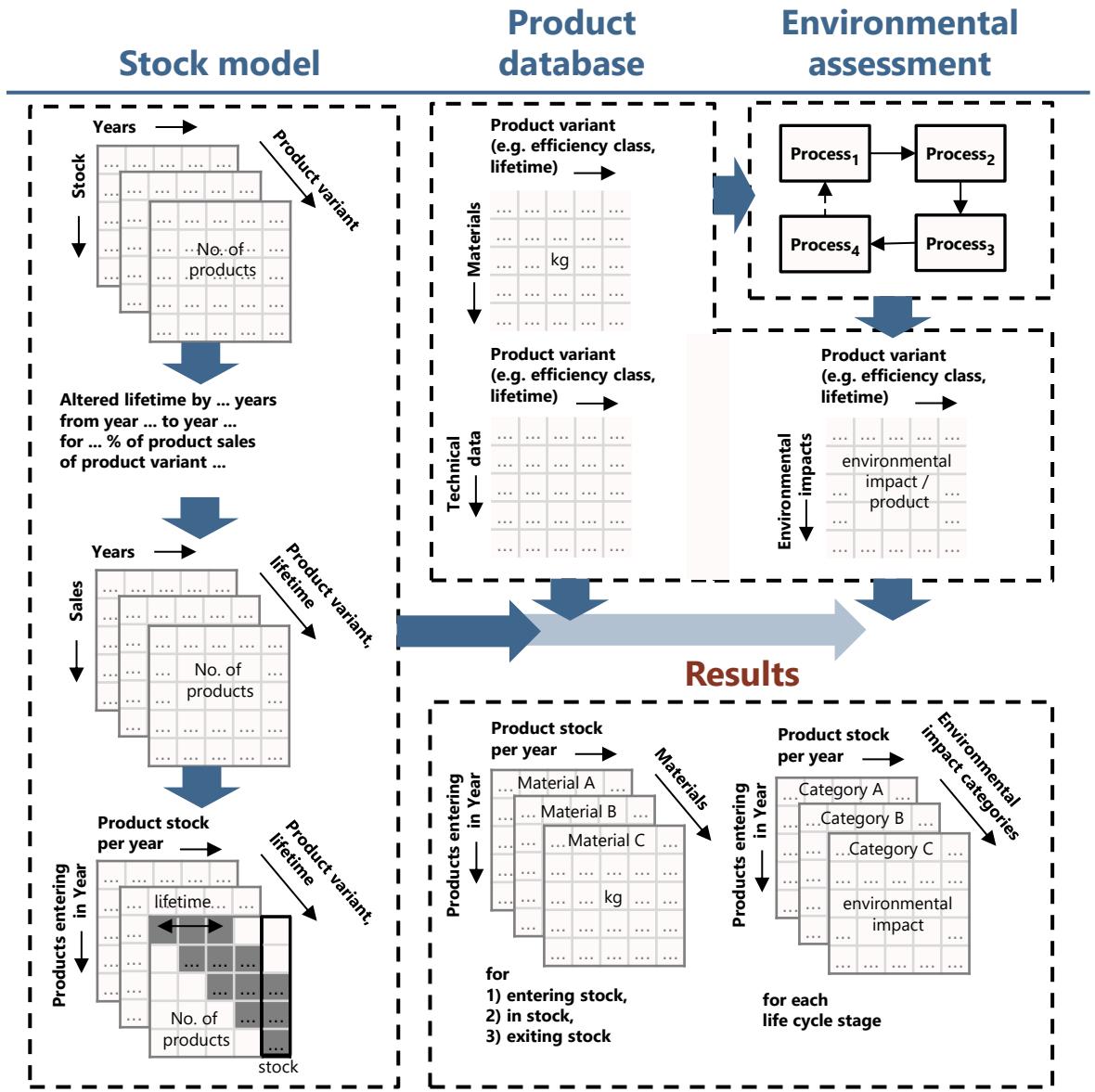
Product database
- interconnector between stock model & environmental assessment
- defines material intensities and other characteristics (energy consumption, efficiency, etc.) of product variants

Environmental assessment
- via emission factors of the electricity mix

Results
- multidimensional impacts over long modelling times
  - on individual product level (materials, environmental impacts)
  - on market level (sales & stocks, material flows, environmental impacts)



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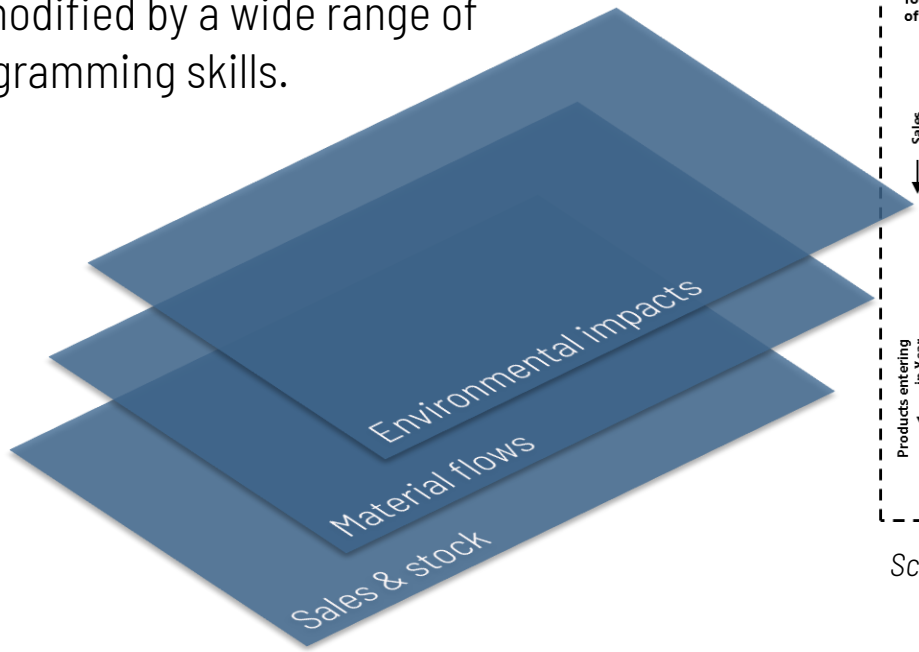
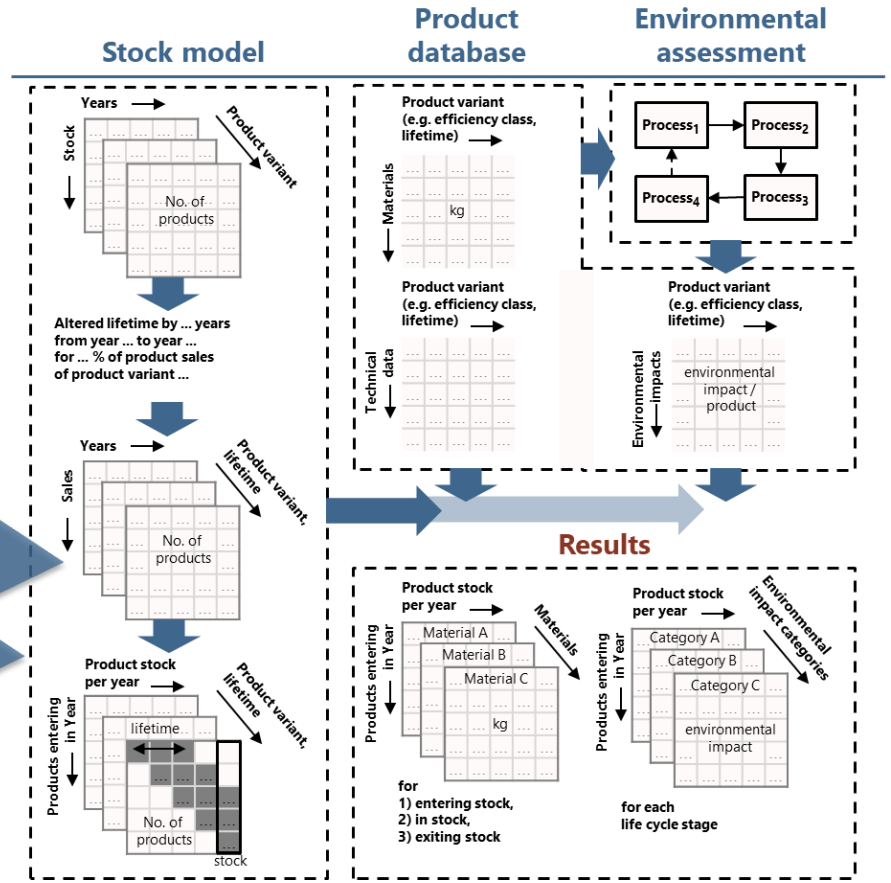
1.3 Underlying logic

- Excel was chosen for the technical implementation due to its widespread use, user-friendly interface, and adequate functionality.
- This choice ensures that the EU-M^3 tool can be accessed, understood, and potentially modified by a wide range of users, beyond those with programming skills.





Schematic representation of the modeling logic

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2. Exploration

2.1 Getting started

2.2 Using the tool

2.3 Policy impacts and monitoring

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2.1 Getting started

Tour-through the model

- EU-M^3 can be downloaded directly from the EU-MORE website
- An online version of the model has been developed for direct access and interaction without any downloads.

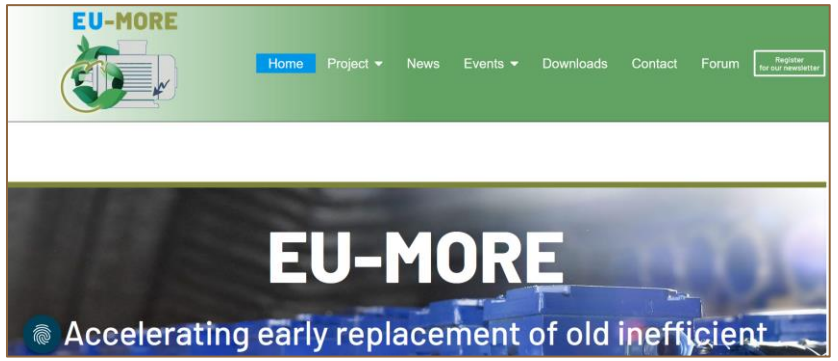
To get started, follow the steps below

1 Open the EU-MORE project website at https://eu-more.eu/

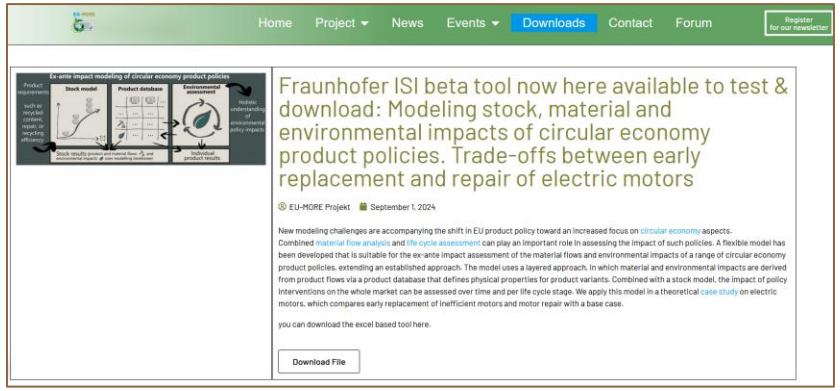
2 Navigate to the Downloads section

3a To download an Excel version on your computer for offline usage:
Look for D4.2 Stock-model to assess the policy impact of motor policies and select Download File

3b To use the web-based version for using or testing the tool online:
Look for D4.2 Stock-model to assess the policy impact of motor policies and select Web-based Excel



Landing page of the EU-MORE website



Download section of the EU-MORE website

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2.2 Using the tool

Info tab

The info tab serves as the landing page of the motor model. It contains information on version history, authors and means of providing feedback.

It provides an overview of the different sheets, including information on the sheets which are hidden by default to keep the tool lean. For interested users on the functioning of the tool, the hidden sheets can be displayed.

Links are provided to documents or scientific articles which provide further information on the model or its underlying logic.

Finally, information is provided on the EU-MORE project.

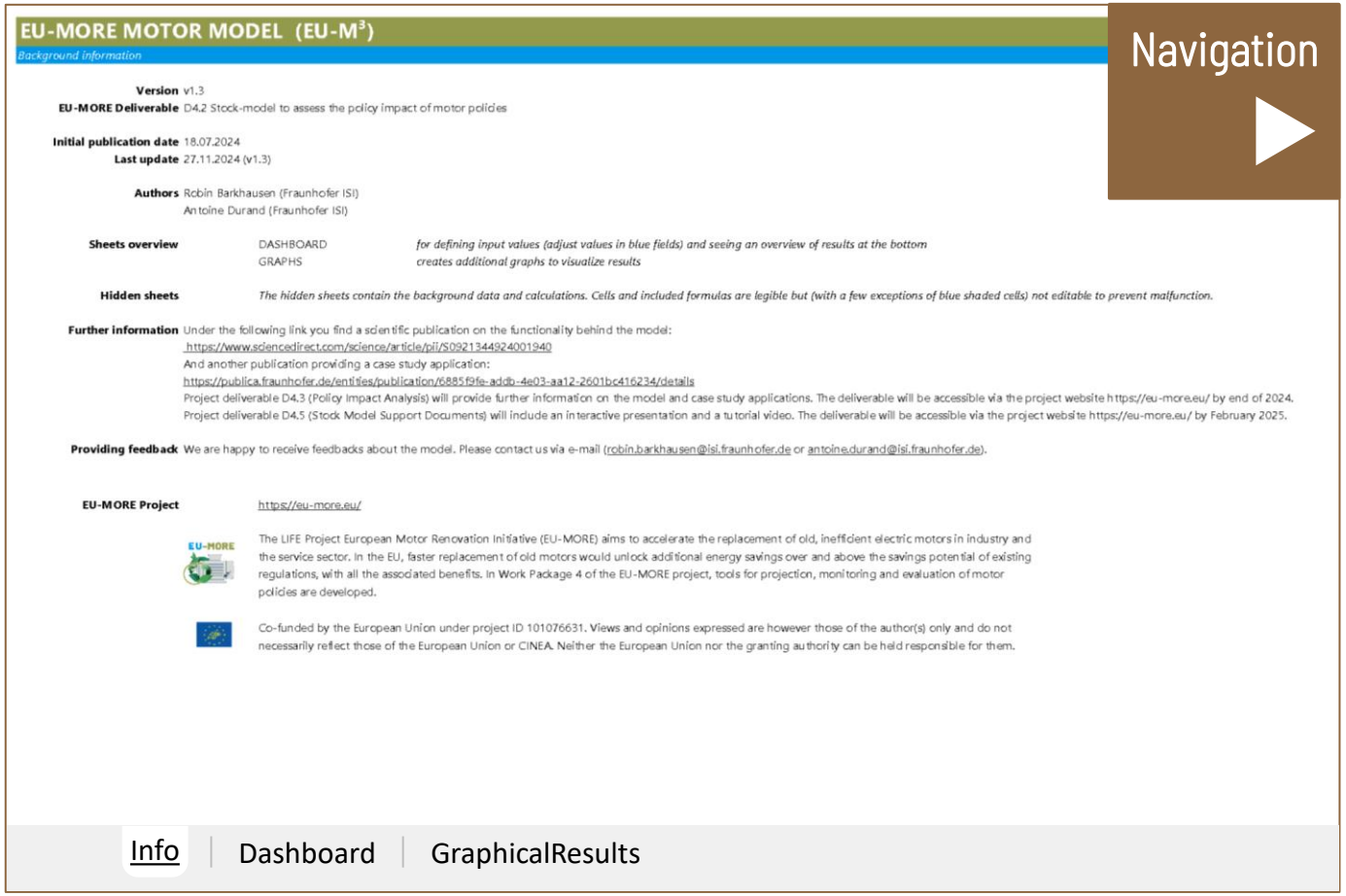

Figure: Click by click tour through the Excel file

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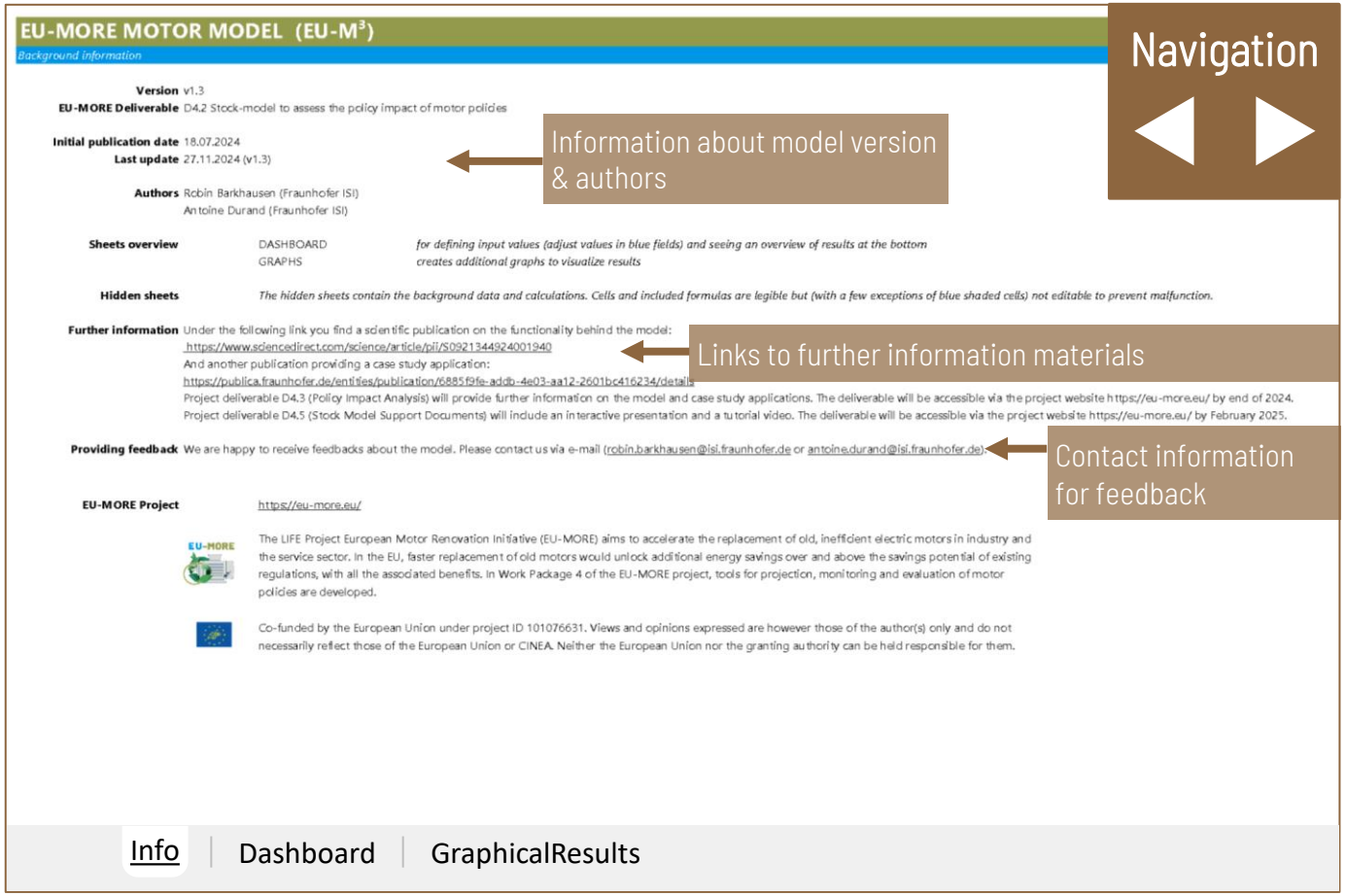

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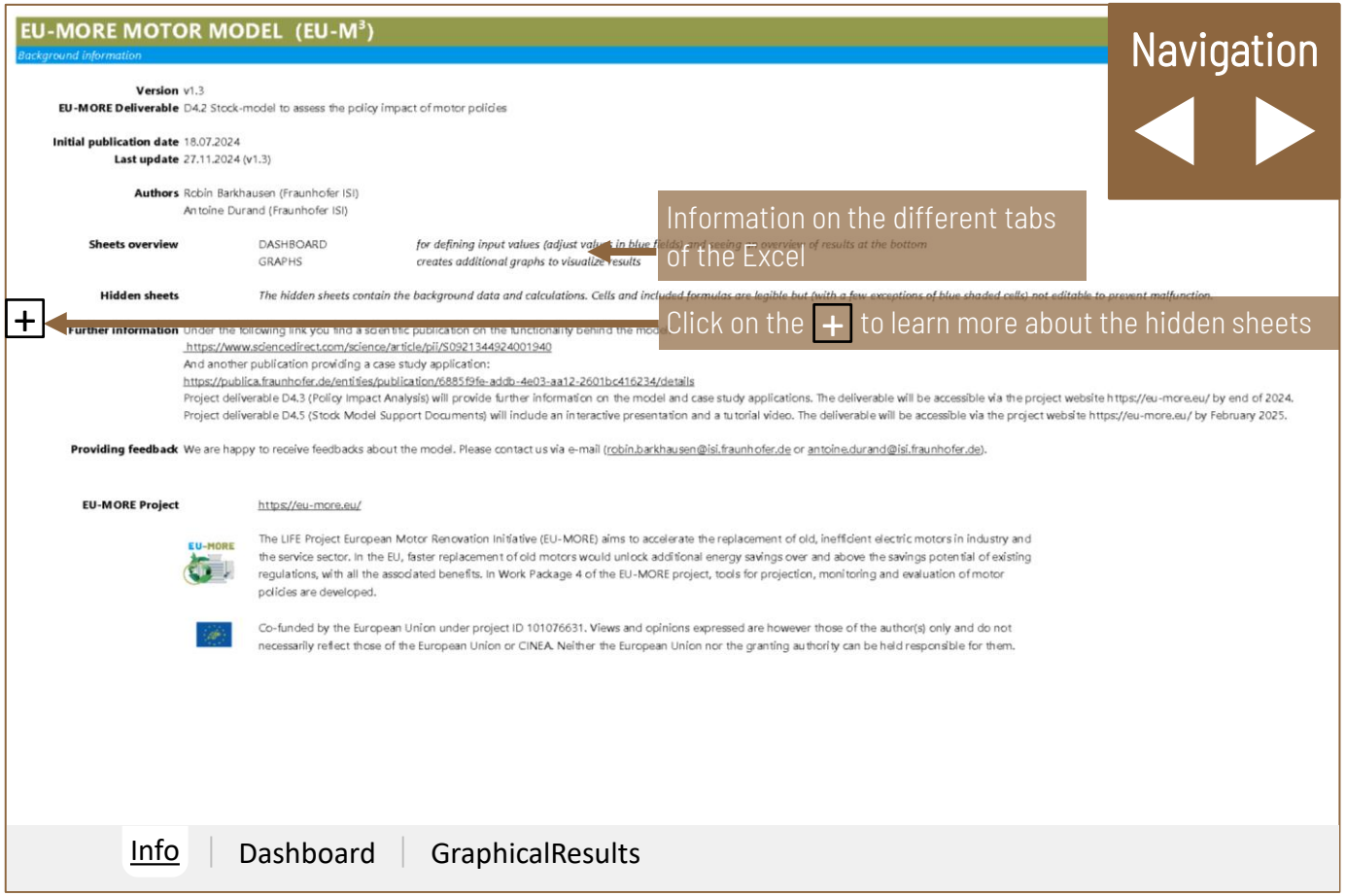

Figure: Click by click tour through the Excel file

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2.2 Using the tool

Info tab

The info tab serves as the landing page of the motor model. It contains information on version history, authors and means of providing feedback.

It provides an overview of the different sheets, including information on the sheets which are hidden by default to keep the tool lean. For interested users on the functioning of the tool, the hidden sheets can be displayed.

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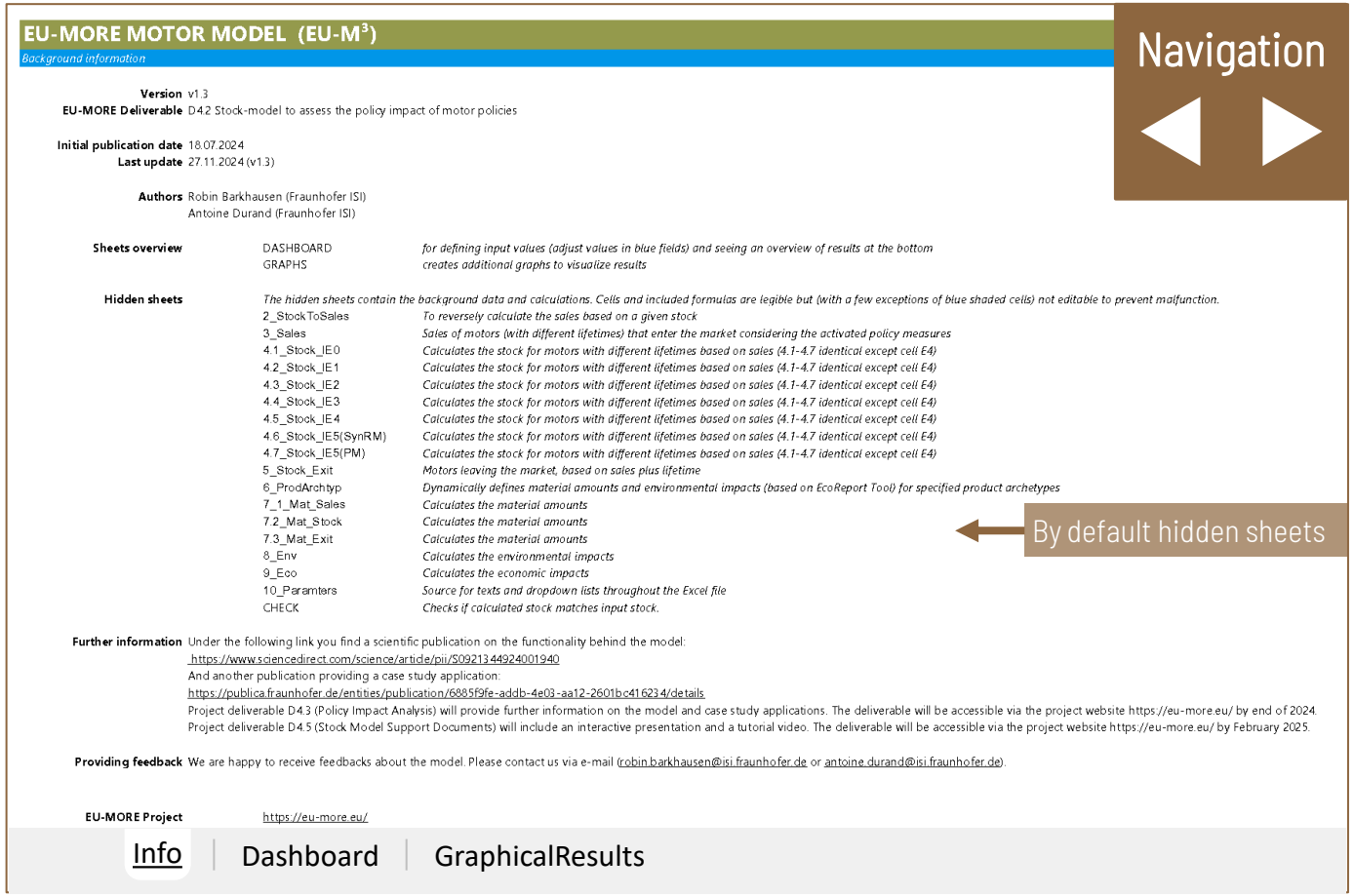

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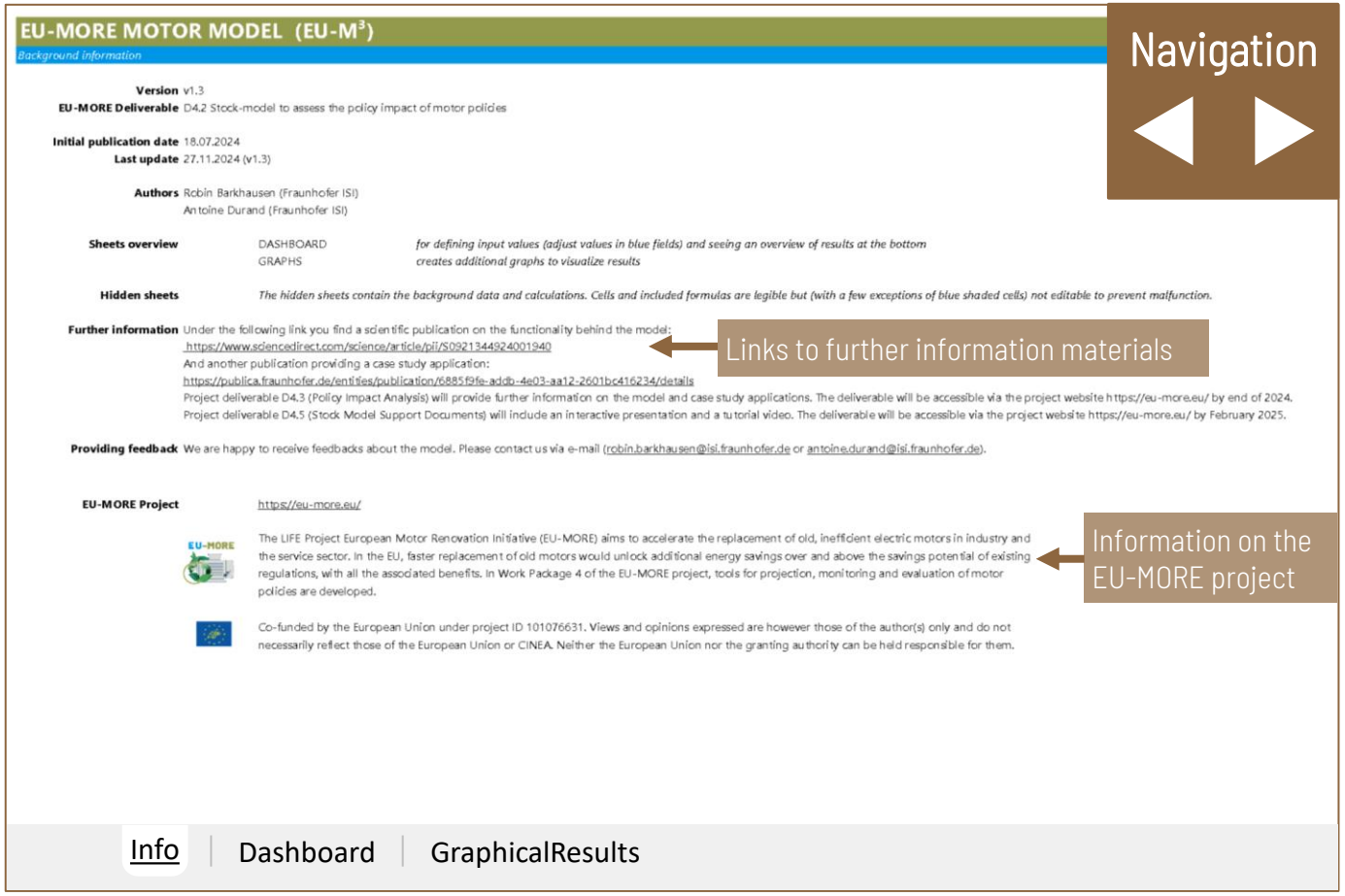

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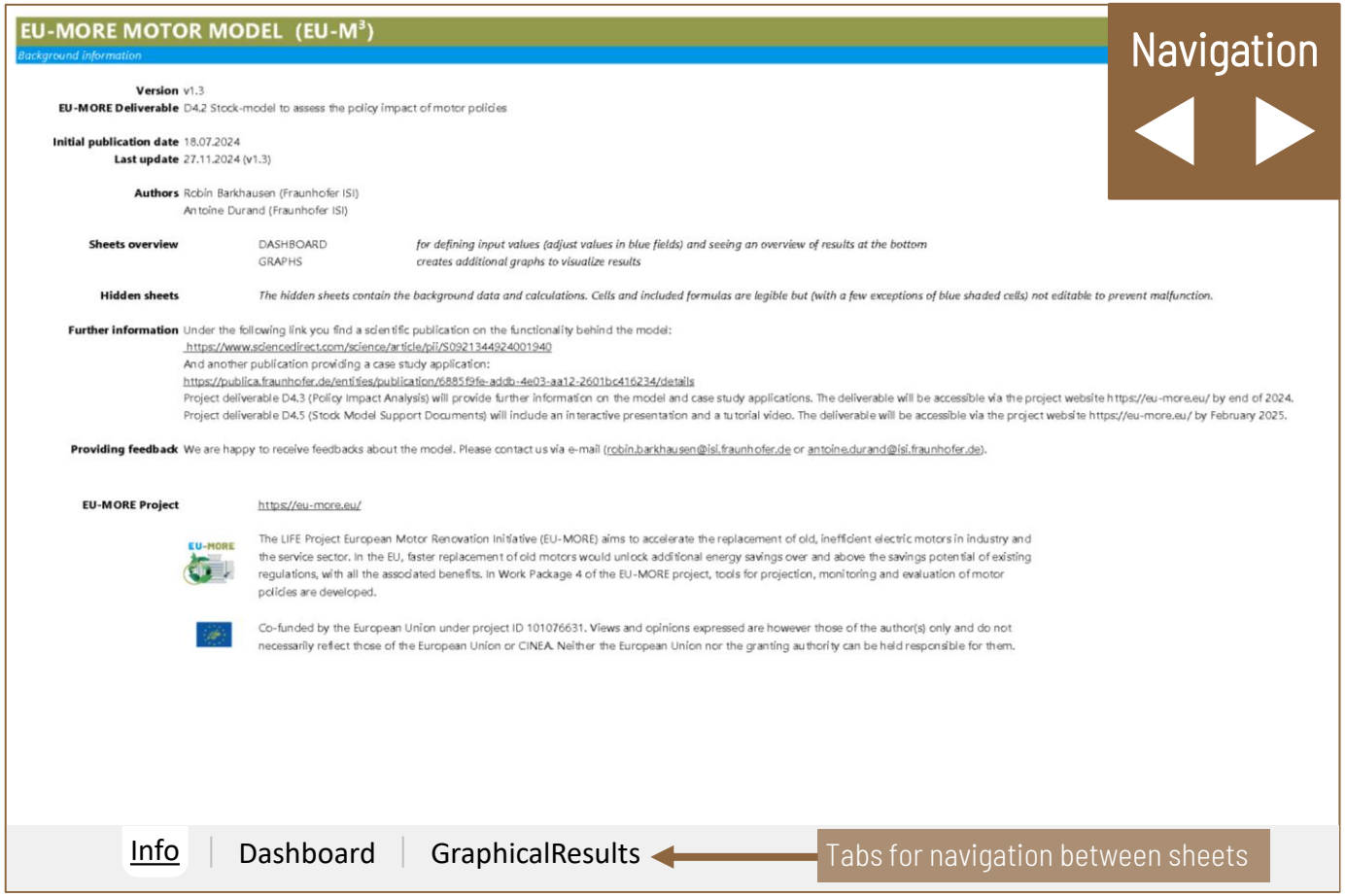
2.2 Using the tool

Navigation between sheets

To move to another sheet, click on one of the tabs at the bottom of the Excel.



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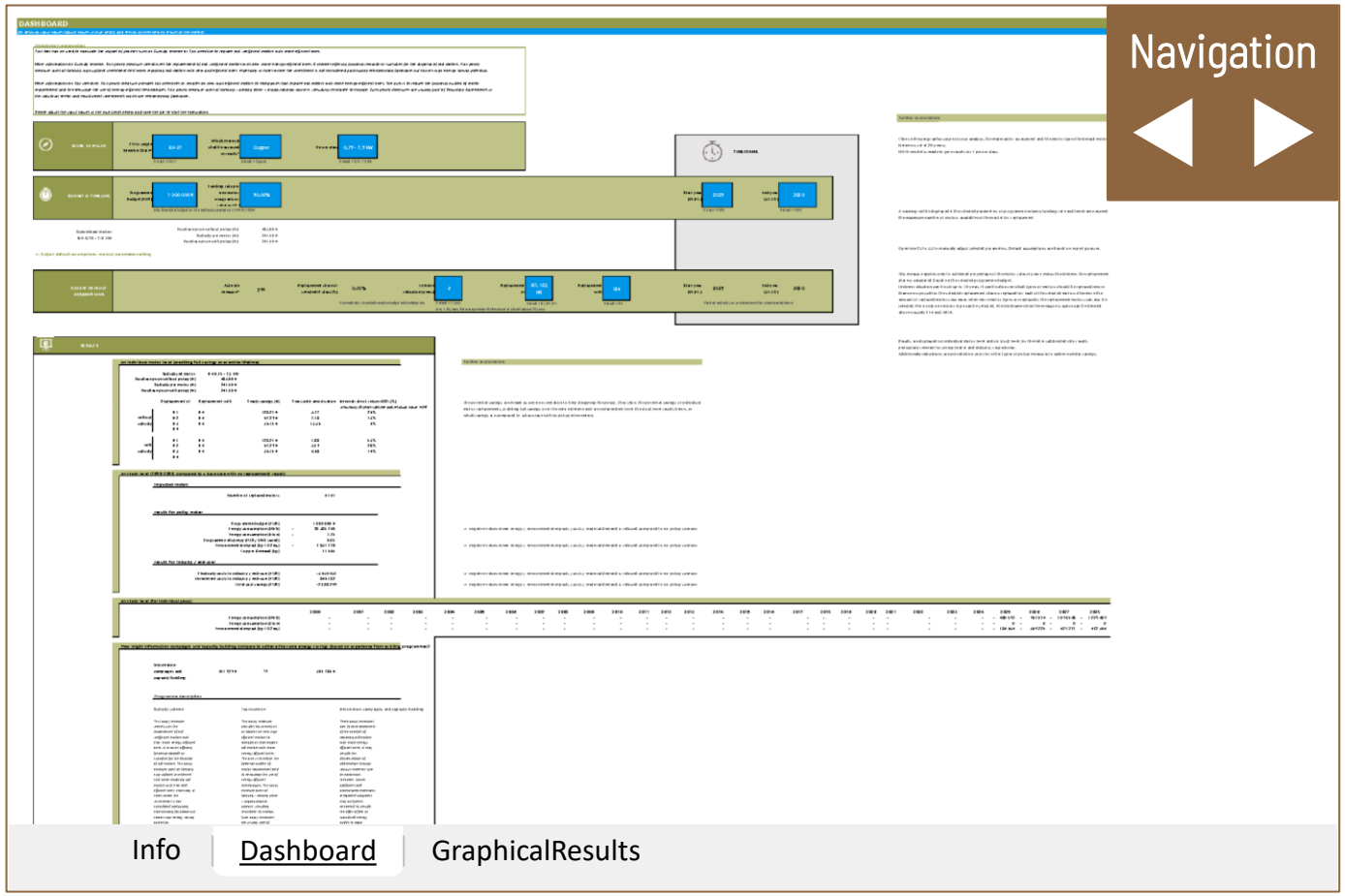
2.2 Using the tool

Dashboard

On the dashboard the user sees information on the policies and further explanation on how to use the tool.



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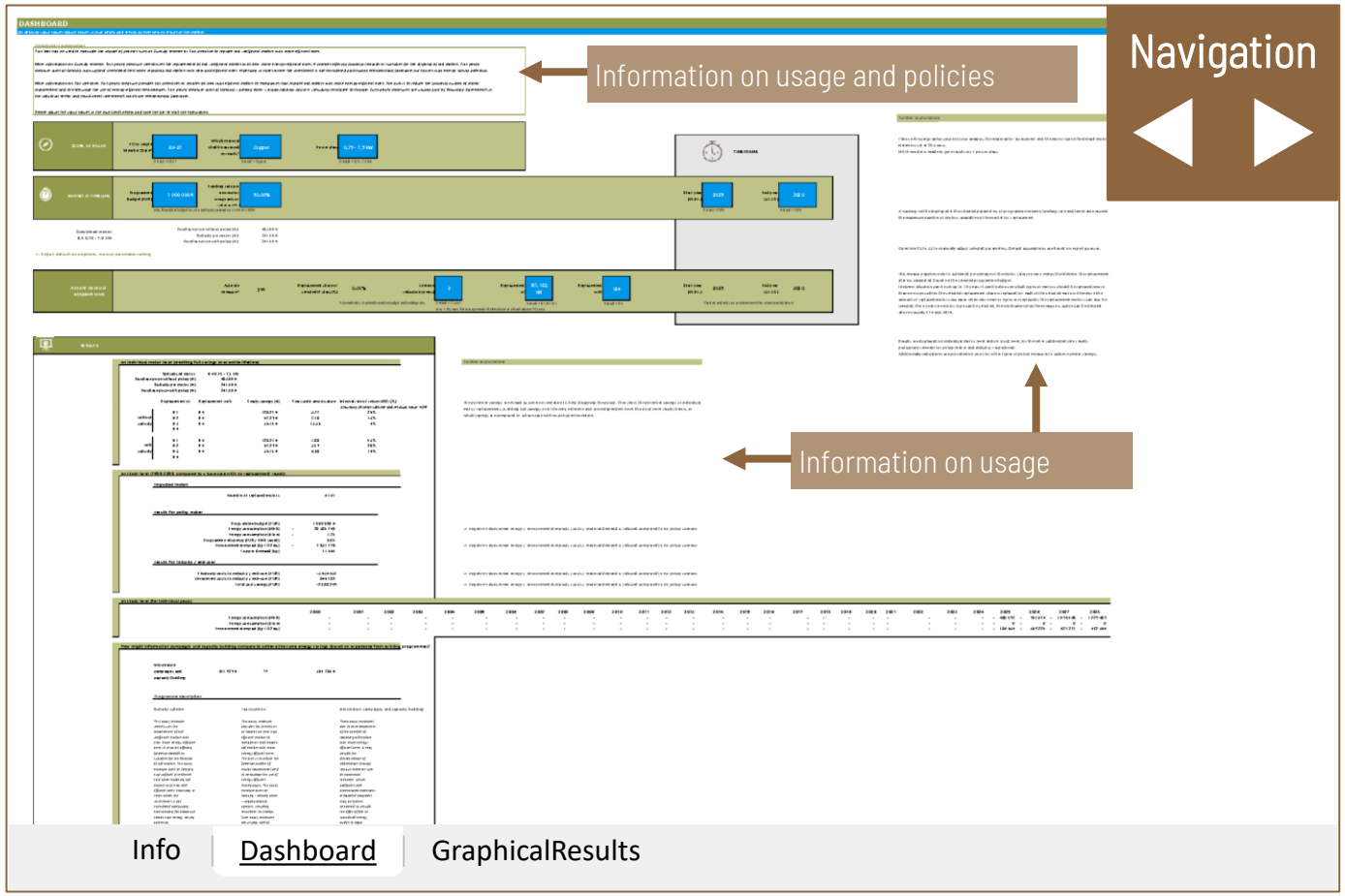

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2.2 Using the tool

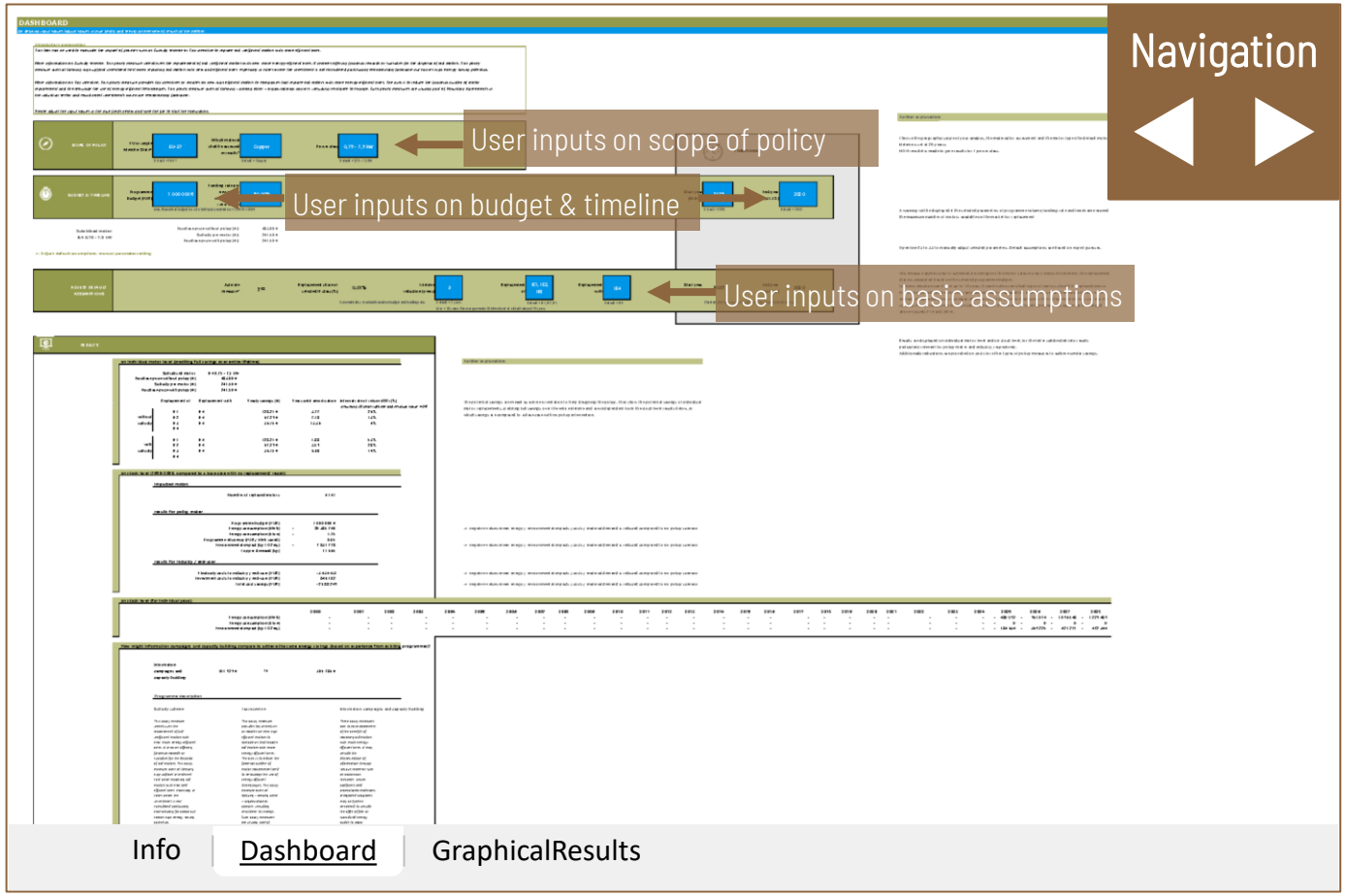
Dashboard

Blue shaded cells are the one where user information can be entered (all other cells are blocked). The following information can be entered:

Scope of policy
- Geographical scope (EU or Member State)
- Material to be assessed (only one at a time)
- Power class (only one power class can be selected)

Budget & timeline
- Programme budget
- Funding rate per new motor (via grants or rebates)
- Start & end year of policy

Basic assumptions (by default hidden but can be adjusted)
- Lifetime reduction (early replacement how many years earlier then technical lifetime)
- Replacement of which efficiency class (several can be selected)
- Replacement by which efficiency class (only one can be selected)



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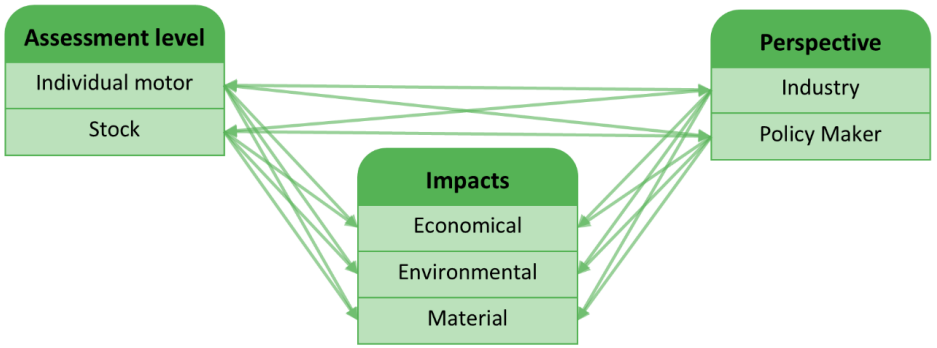
2.2 Using the tool

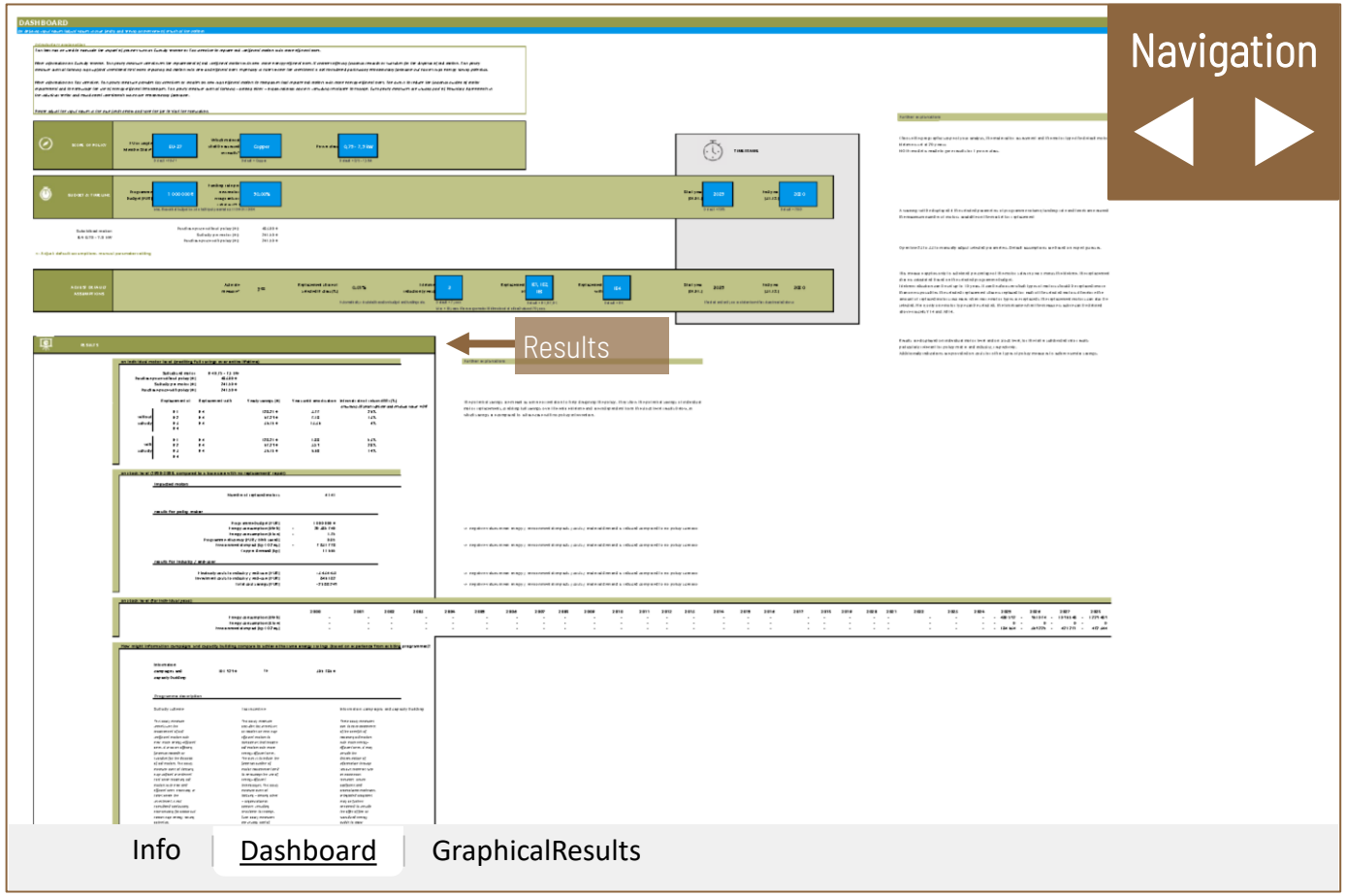
Dashboard

Automatic calculations are disabled in the Excel file to facilitate usage. After entering all information, the calculation is started by either saving the Excel file, clicking *Data* > *Refresh All* or use your keyboard shortcut to recalculate all formulas. Calculation might take up to 40 seconds depending on local computing capacity.

Results are then directly displayed at the bottom of the sheet.

They are grouped into those on motor and on stock level, from industry and policy maker perspective and for economical, environmental and material aspects. Further information on the results is provided in part 3. Application.





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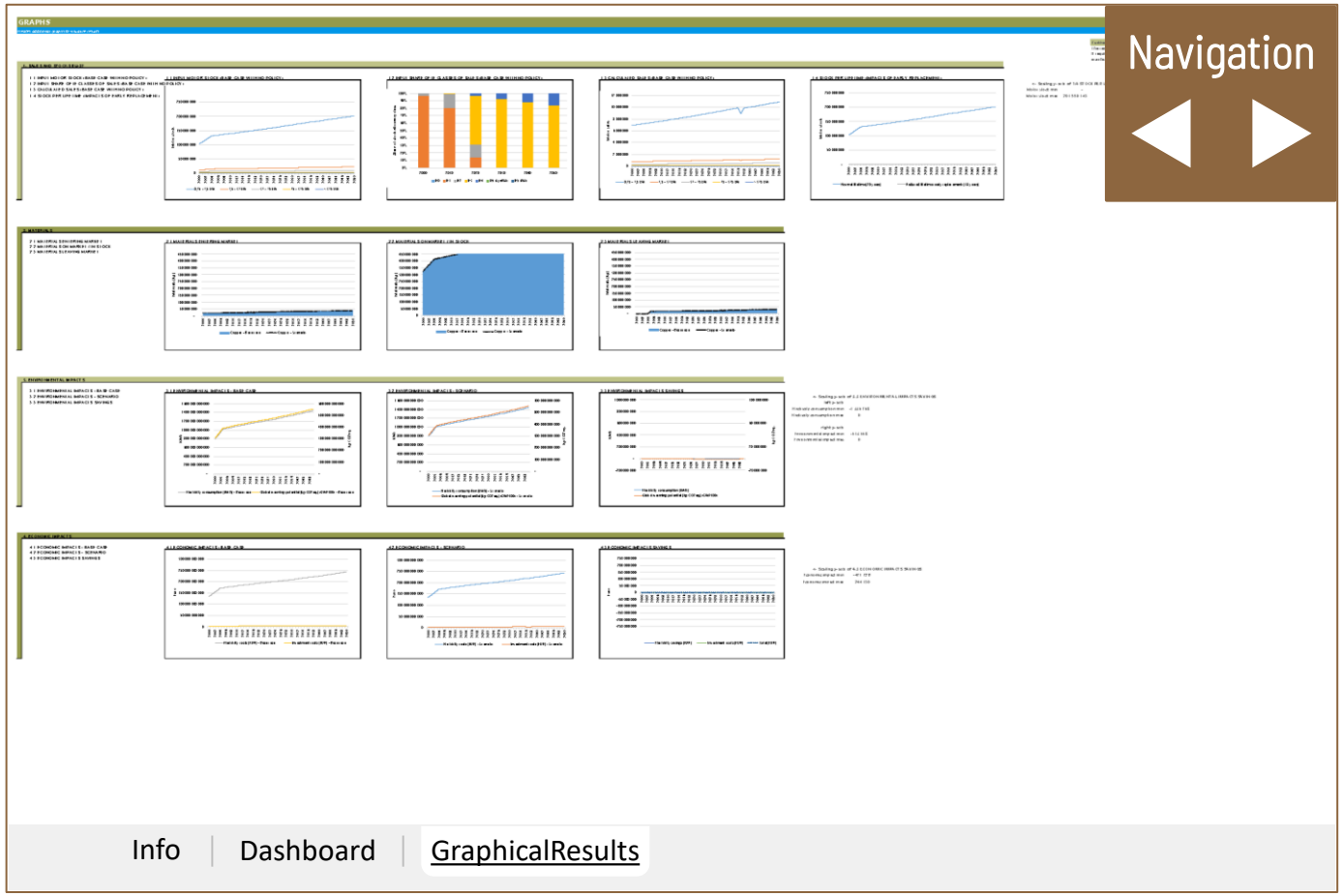
2.2 Using the tool

Graphical results

The Graphical results sheet extends the numerical values on the Dashboard.



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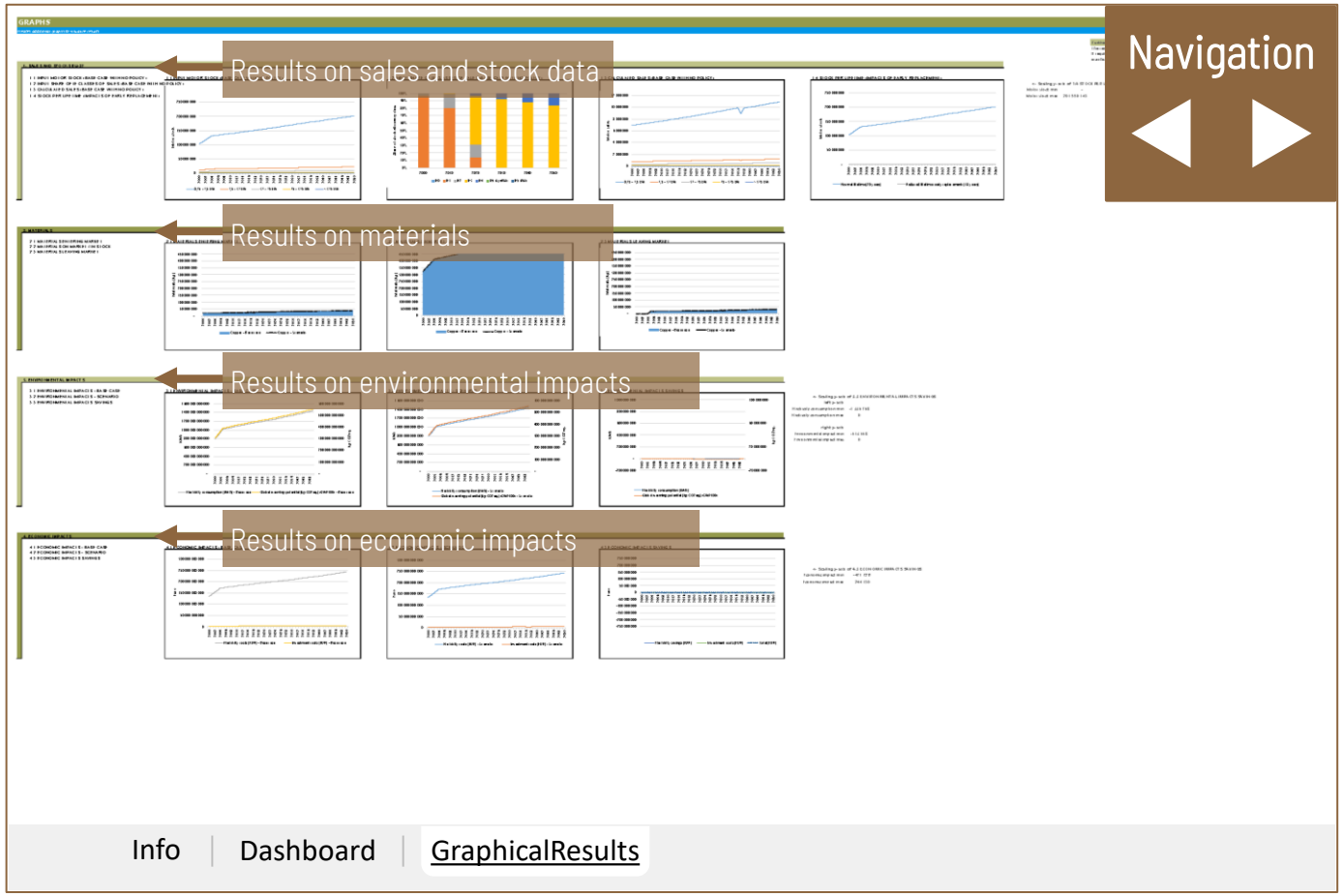
2.2 Using the tool

Graphical results

Graphs are divided into those related to sales and stock data, materials, environmental impact and economic impacts.
Due to the possibility to enter individual policy parameters, the scaling of the y-axis might have to be manually adjusted by clicking on the graph. For some of the graphs, the minimum and maximum values are automatically provided.



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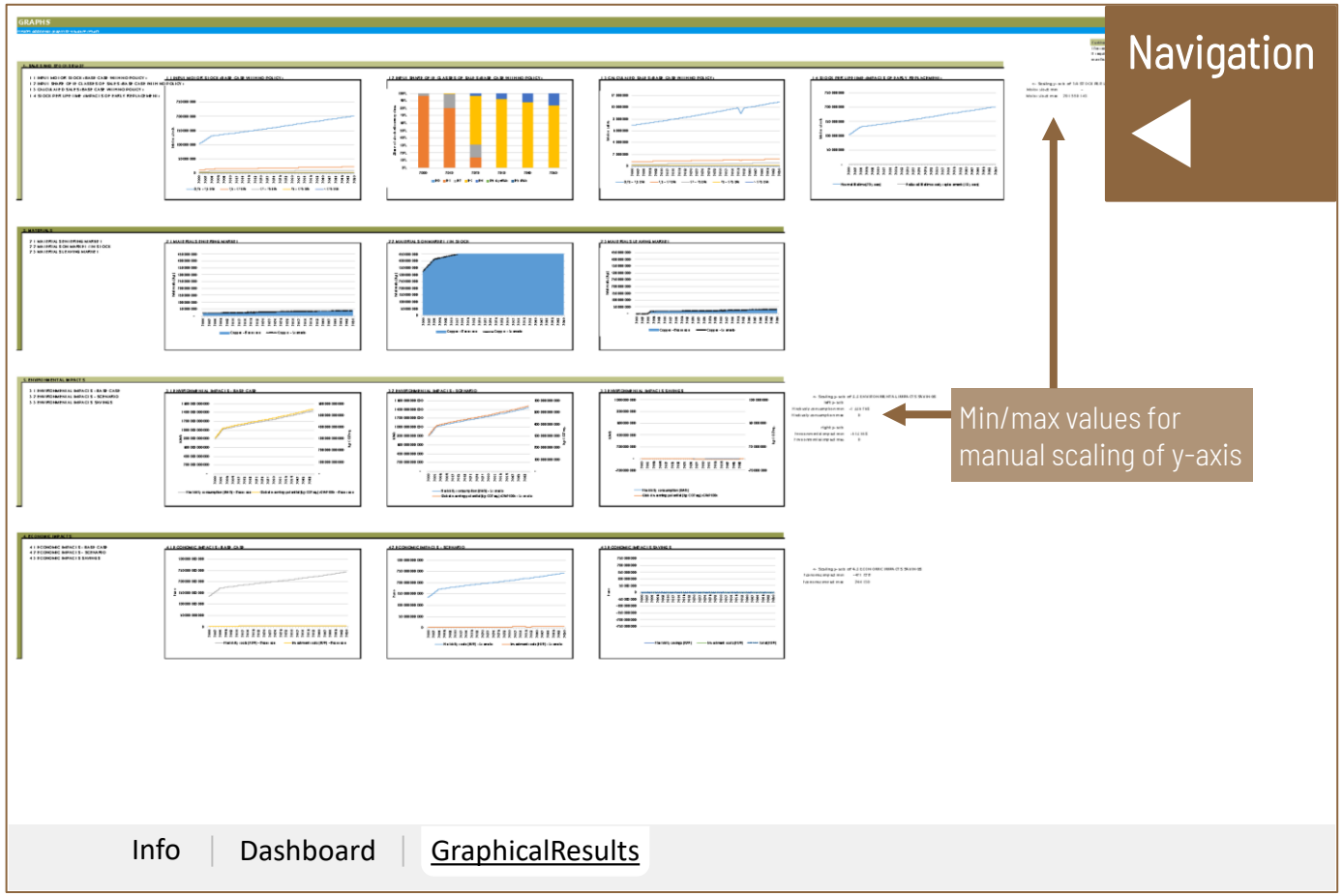
2.2 Using the tool

Graphical results

Due to the possibility to enter individual policy parameters, the scaling of the y-axis might have to be manually adjusted by clicking on the graph. For some of the graphs, the minimum and maximum values are automatically provided.

Further information on the results is provided in part 3. Application.



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2.3 Policy impacts and monitoring

Additional information on how savings are calculated

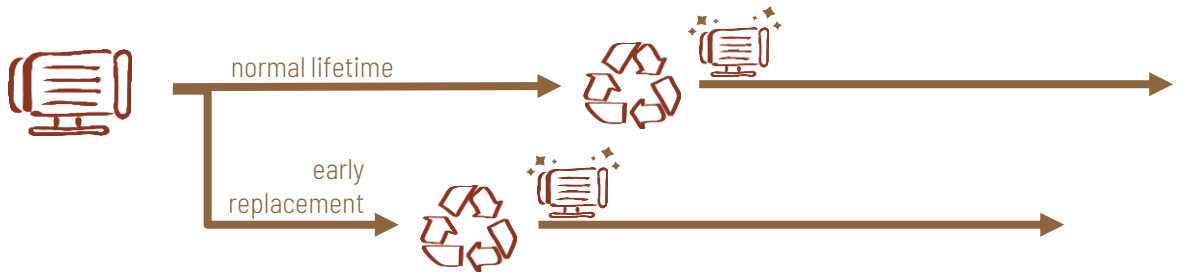
- The motor model calculates savings compared to a base case with no policy intervention.
- Savings are only counted for the years in which motors are removed from the market before their technical lifetime.
- A two-year reduction in lifetime in the policy scenario leads to a delay in replacing motors in the base case, with corresponding savings occurring for those two years.
- If the replacement motor is better than the market average at the end of the technical lifetime, then the savings are realized over the entire lifetime of the new motor.
- These savings apply to energy consumption, CO2 savings, and energy costs.

EU Energy Efficiency Directive 2023

Annex V COMMON METHODS AND PRINCIPLES FOR CALCULATING THE IMPACT OF ENERGY EFFICIENCY OBLIGATION SCHEMES OR OTHER POLICY MEASURES UNDER ARTICLES 8, 9 AND 10 AND ARTICLE 30(14)

1. Methods for calculating energy savings other than those arising from taxation measures for the purposes of Articles 8, 9 and 10 and Article 30(14).
Obligated, participating or entrusted parties, or implementing public authorities, may use the following methods for calculating energy savings: [...]
2. In determining the energy savings for an energy efficiency measure for the purposes of Articles 8, 9 and 10 and Article 30(14), the following principles apply: [...]

(m) for policies that accelerate the uptake of more efficient products and vehicles, except those newly implemented as from 1 January 2024 regarding the use of direct fossil fuel combustion, full credit may be claimed, provided that it is shown that such uptake takes place before the expiry of the average expected lifetime of the product or vehicle, or before the product or vehicle would usually be replaced, and the savings are claimed only for the period until the end of the average expected lifetime of the product or vehicle to be replaced; [...]



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2.3 Policy impacts and monitoring

Additional information on how savings are calculated

- The calculation of the Internal Rate of Return (IRR) at the individual motor level is an exception. This calculation is intended as a decision-making aid for policy design and represents a hypothetical company perspective.

- The current form of the tool does not directly allow for consideration of only savings beyond the minimum technical requirement.
  nevertheless possible to do it → the user must carry out two almost identical calculations, one with the old motor replaced with the minimum standard and one with the more efficient option. The difference between the two represents the savings.

- The user can model an exchange obligation by setting the funding rate to 0%.

EU Energy Efficiency Directive 2023

Annex V COMMON METHODS AND PRINCIPLES FOR CALCULATING THE IMPACT OF ENERGY EFFICIENCY OBLIGATION SCHEMES OR OTHER POLICY MEASURES UNDER ARTICLES 8, 9 AND 10 AND ARTICLE 30(14)

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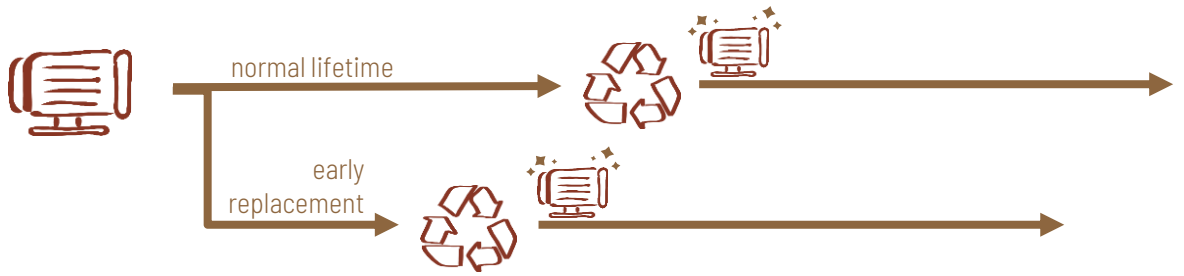

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3. Application

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

3.1 Theoretical case study

Introduction

- €2,000,000 subsidy program.
- Country similar to Belgium or Netherlands (in terms of electricity production).
- Program funds 50% of new motor costs (aligns with schemes like the Portuguese Energy Efficiency Promotion Plan)
- Policy for motors from 37 - 75 kW, active 2025 - 2030.
- Early replacement of IE1 and IE2 motors with IE4 motors.
- Example is theoretical, limitations discussed in section 4.
- All user inputs displayed on the right.

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

Table: User input for theoretical case study

Link to D4.3 Policy impact analysis
Barkhausen, R.; Durand, A.; Ntaras, N.; Eichhammer, W. (2024)

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3.1 Theoretical case study

Results

- Key outcomes displayed on Dashboard tab after running calculation in Excel file.
- Shows motor and stock level results, industry and policy maker perspectives, economic, environmental, and material impacts.

Stock level results

- Program replaces 1,206 motors between 2025 and 2030.
- Total energy savings of 34.21 GWh until 2050
  - (10.35 GWh saved 2025-2030)
- Also yearly savings displayed
- €5,763,645 in electricity cost savings and €1,673,217 in additional investments for IE4 motors.

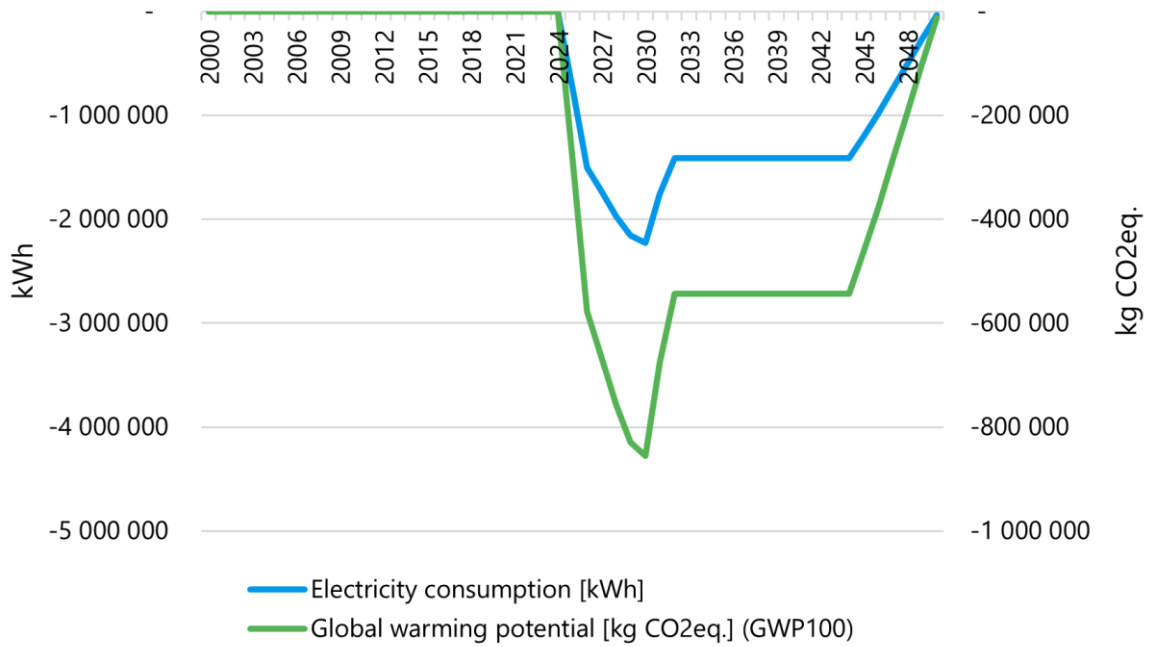

Figure: Example graphical results: environmental impact savings by early motor replacement

Link to D4.3 Policy impact analysis
Barkhausen, R.; Durand, A.; Ntaras, N.; Eichhammer, W. (2024)

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3.1 Theoretical case study

Results

Environmental impacts

- 34.21 GWh energy savings equals GHG savings of 12.14 thousand tonnes CO2eq.

Material impacts

- Early replacement with IE4 motors raises demand for copper by 26.02 tonnes.

- Maximum theoretical budget of €132,784,586.
- Maximum energy savings of 2,271.36 GWh and environmental savings of 872.61 thousand tonnes CO2eq.

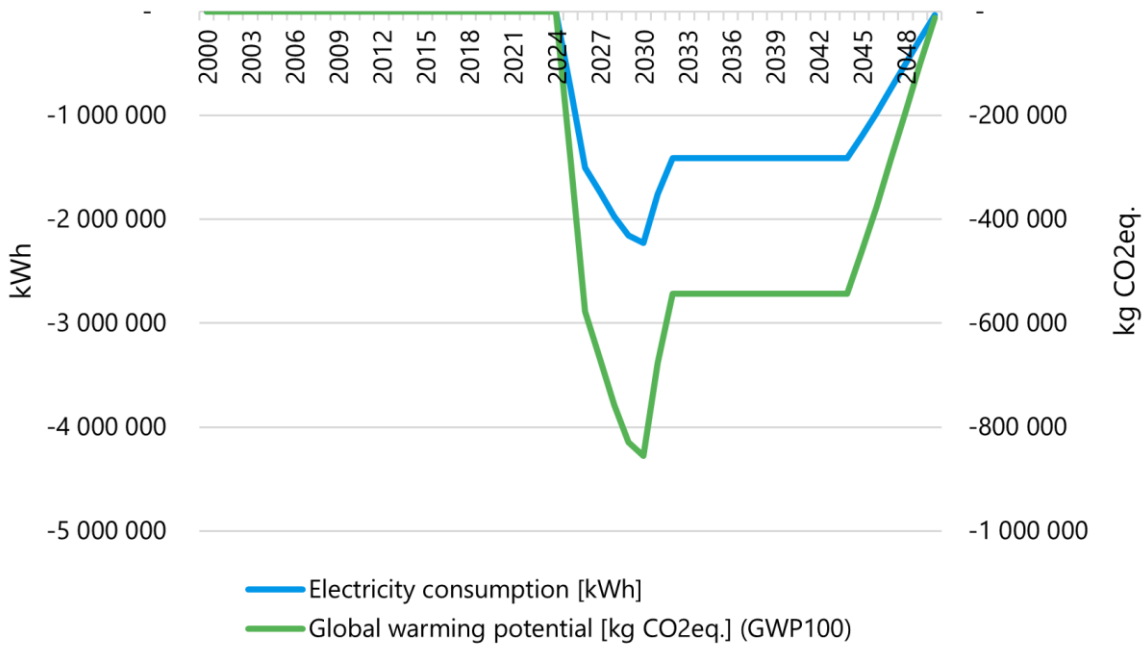

Figure: Example graphical results: environmental impact savings by early motor replacement

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3.2 Practical example 1

Introduction

- Assessment of the Portuguese Energy Efficiency Promotion Plan (PPEC) as a representative subsidy scheme.
- 6th edition incentivized High Efficiency Motor installations in manufacturing, agriculture, and fisheries.
- Incentive of 51.1%, totaling 896,767€, for replacing low-efficiency motors.
  Quick motor usage assessment for proper replacement motor dimensioning.

Model Assumptions:

- Excluded IE0 motors, assumed replacement of IE1 motors.
- Assumed replacement motors to be IE4.
- Assumed lifetime reduction of 5 years for IE1 motors.
- Power range encompassed all power classes in our model.
- Chose 37-75 kW range to represent average power consumption and investment costs due to data scarcity.

Challenges:

- Importance of available data.
- Difficulty in accurately representing nuances like sector exclusion, installation cost coverage, or motor dimensioning.

User inputs

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

Table: User input for practical example 1

Link to D2.2 Review of past and existing policies for the acceleration of electric motor renovation
Faassen, E.; Eichhammer, W.; Sangiorgio, I. (2024)

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3.2 Practical example 1

Results

- €896,767 budget and 51.10% funding resulted in 529 motor replacements, 26% higher than actual program (420).
    - Might be due to the fact that 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
- Replaced IE1 motors represent 4.78% of all replaceable IE1 motors from 2017-2018.
- Exchanging IE1 with IE4 motor gives 16% IRR and 5.93 years until break-even.
- Program triggered motor investments of €249,147, resulted in €3,131,171 energy cost savings (overall net benefit of €2,882,024).
- 22.36 GWh energy consumption reduction.
- CO2eq savings of 8.59 thousand tonnes, cost-effectiveness ratio of €0.04/kWh saved → vs. € 0.008/kWh reported by the scheme
- Additional 4.91 tonnes of Copper for IE4 motors until 2050.

Limitations:

- Discrepancies with reported figures due to data limitations and modeling simplifications.
- More detailed input data set might bridge these gaps.
- Highlighting inherent complexities and uncertainties in projecting and assessing impacts of policy measures.

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3.3 Practical example 2

Introduction

- Assessment of the Dutch Energy Investment Allowance, a tax incentive.
- Companies can deduct 45.5% of investment costs from taxable profit.
- Assuming a corporate tax rate of 20%, this results in a 9.1% funding rate per motor.
- Motors with a nominal power of less than 75 kW qualify for funding.
- Program budget for 2023 is €249,000,000, unclear portion for motor replacements.
- Assumed 1% share of budget for 0.75 – 7.5 kW power class. This power class represents a fraction of overall motor market.
- Assumptions are reported in the table on the right.

User inputs

Geographical scope (EU or Member State)	Netherlands
One material for impact assessment	Copper
Power class of impacted motors	7.5 – 37 kW
Programme budget	€2,490,000
Funding rate per new motor	9.10%
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 years
Replacement of efficiency level (more than one class can be selected)	IE1
Replacement by efficiency level	IE4

Table: User input for practical example 2

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3.3 Practical example 2

Results

- Budget of €2,490,000 projects energy savings of 337.77 GWh and environmental savings of 129.77 thousand tonnes CO2eq.
- Program efficiency of €0.01/kWh saved or €0.019/kg CO2eq saved.
- Comparable to €0.014/kg CO2eq saved as reported by Dutch scheme.
- Model estimates extra demand of 91.58 tonnes of Copper until 2050.

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4. Reflection

3.1 Prerequisites

3.2 Limitations

3.3 Future

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4. Reflection

4.1 Prerequisites

- EU-M^3 model results depend on quality of user inputs and background data.
- Data sources come from previous tasks of EU-MORE project and literature.
- Reliability of data sources varies.
- Simplifications in background data necessary, such as setting a static lifetime for all motors. → In reality, motor lifetime follows a distribution function, potentially resulting in longer lifespan. Current model design works with a fixed lifetime representing the average lifetime of motors.

4.2 Limitations

- Model has necessary simplifactions that impact accuracy (e.g. country scaling based on gross electricity production as a proxy for industry size).
- Can apply policy to one selected power class per calculation.
- Requires significant computing time due to numerous background calculation steps.
- Calculated cost efficiencies can align with practical policy examples, but model's estimates should be interpreted with caution due to simplifications and assumptions

4.3 Future

- EU-M^3 model provides useful insights but results depend on quality of inputs and underlying data.
- Future improvements could include refining data inputs and assumptions for enhanced accuracy.
- More accurate data on motor lifetimes or refined country scaling method could yield more precise estimates.

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Thank you

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robin.barkhausen@isi.fraunhofer.de
Fraunhofer Institute for Systems and Innovation Research ISI

Further materials can be found on the EU-MORE project website, including

- Deliverable D4.2 → EU-MORE Motor Model (EU-M³)
- Deliverable D4.3 → report on policy impacts (soon available)

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

Back-up: Further explanation on theoretical case study

Additional information

- 2025 to 2030, the policy is active and replacements of IE2 motos with higher efficiency IE4 motors generate savings.
- From 2027, replacements are still occurring, but IE2 motors that have not been replaced (replacement share is lower than 100%) are replaced at the end of their technical lifetime with market average, leading to a flattening of the curve.
- 2031 to 2032, a reduction in savings occurs as no additional replacements occur and unaffected motors keep getting replaced after their technical lifetime.
- 2033 to 2044, replaced motors keep generating savings, creating a balance with continued savings.
- 2045-2050, as replaced motors exit the market and are replaced with market average, energy consumption realigns with the base case.

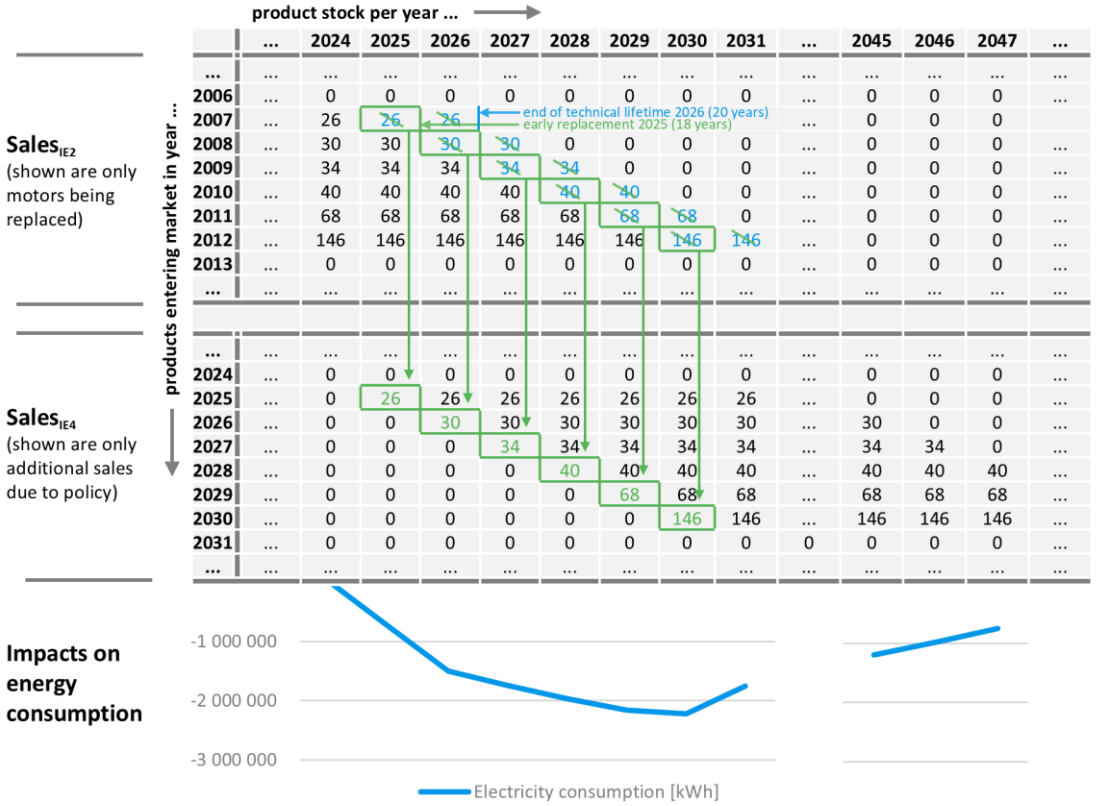

Figure: Explanatory representation of sales, stocks, and savings (replacements of IE3 motors are not shown but follow the same logic)

Link to D4.3 Policy impact analysis
Barkhausen, R.; Durand, A.; Ntaras, N.; Eichhammer, W. (2024)

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