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ETC technical paper

Drivers and sector disaggregation of projections and trajectories

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Description

This technical paper provides a thorough analysis of recent research conducted within the European Topic Centre on Climate Mitigation (ETC CM) on the drivers influencing greenhouse gas (GHG) emissions projections and trajectories across various sectors within the European Union (EU) Member States (MS). It aims to identify key factors shaping GHG projections and investigates sector-specific disaggregation to uncover cross-sectoral trends. Projections of GHG emissions are essential for evaluating countries' progress towards their set targets.

This report describes the approach and results of three main methodological activities, as follows:

1. Assessing differences in GHG emission trends to quantify disparities in historic and future sectoral emission trends among MS.
2. Evaluating the consistency between PaMs and emission scenarios by assessing the impact of key EU policies on GHG emissions and examining differences between the WEM and WAM scenarios.
3. Conducting a qualitative assessment of included and excluded drivers in the projections to identify key sector drivers through consultation of technical reports and information used by MS in preparing projections.

The results and conclusions of the report provide recommendations for enhancing the quality assurance and quality control (QA/QC) of the ETC CM on GHG emission projections and national integrated climate and energy Policies and Measures (PaMs) under the Regulation Governance of the Energy Union and Climate Action (EU) 2018/1999.

1 Introduction

Member States (MS) are required to report on the country's Greenhouse gas (GHG) emission projections and national integrated climate and energy Policies and Measures (PaMs) under the Regulation Governance of the Energy Union and Climate Action (EU) 2018/1999 (Gov. Reg.) every two years (EU, 2018). This data is quality-checked by the ETC CM and subsequently used in several analysis and reports, such as the Trends and Projections report (ETC CM, 2023a). GHG projections are an important information source to assess if countries are on track to achieve their mitigation targets.

In this study, we delve deeper into the reporting of MS to identify the primary drivers of GHG emissions at the most detailed disaggregation level possible. We aim to assess their impact on projections and evaluate the consistency between PaMs and projections, considering MS reporting, with the ultimate objective of improving the quality control (QC) activities on the ETC CM on projections and PaM reporting.

The objectives of the study include:

- Gain a better understanding of the differences in GHG emissions projection trends among MS and what the main driving forces are explaining these differences.
- Gain a better understanding of the key PaMs and how these are projected to affect GHG emission trends.
- Conclusions and recommendations to improve quality-checking of reported information on GHG projections.

To achieve these objectives, the study is divided into three interlinked methodological steps:

1. Assessment of drivers and GHG emission trends.
2. Assessment of the consistency between the reported PaMs and emission projection scenarios.
3. Qualitative assessment of both the drivers currently included into the projections and those drivers currently excluded but bearing significant potential impact.

The main data source for the analysis is the data reported by MS on GHG Projections (ETC CM, 2023b) and integrated national climate and energy policies and measures (ETC CM, 2023c) Pursuant to Gov. Reg.

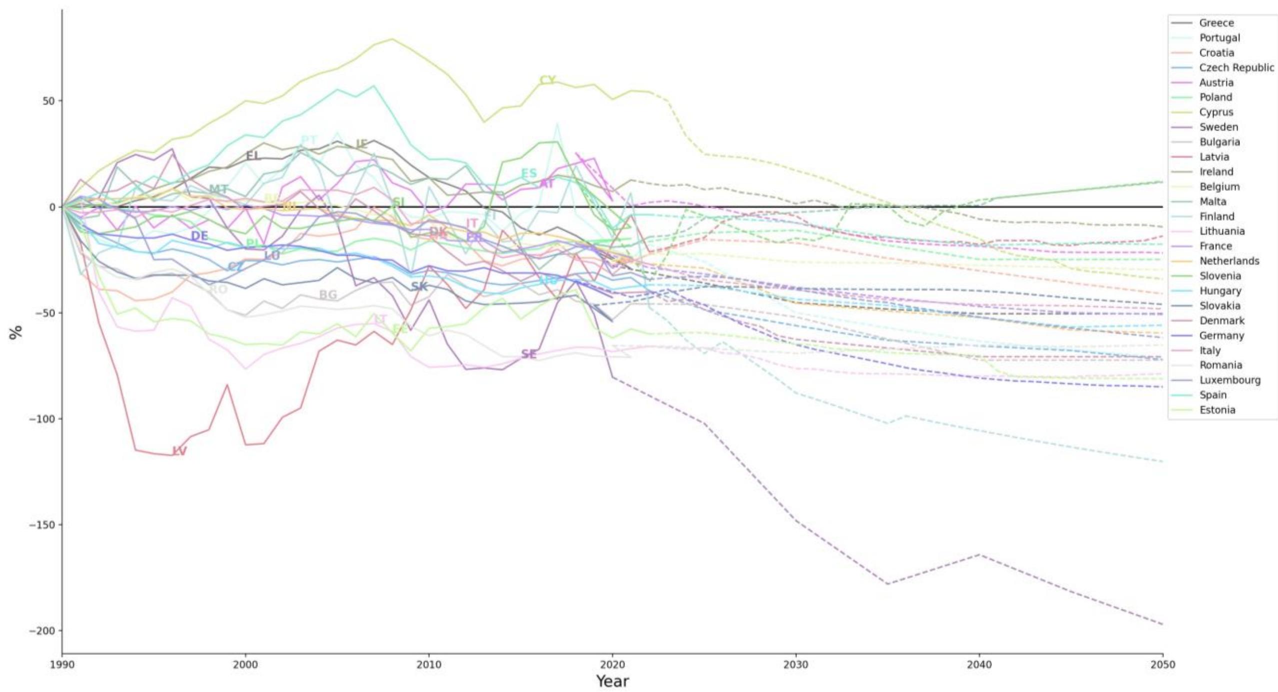
The paper is structured in the following manner. Chapter 2 consists of a review of relevant literature, using mainly research papers on the subject. The methodological approach and detailed steps adopted in the study are described in Chapter 3. Chapter 4 then presents the results of the analysis together with a discussion on the findings. Final conclusions of the analysis are drawn in Chapter 5 leading to recommendations to enhance the accuracy, consistency, and effectiveness of reporting. Chapters 3 and 4 are structured into three parts dealing with each methodological step as identified above.

2 Literature review

The EU has been continuously updating its climate regulation framework with the aim of reducing GHG emissions to achieve climate-neutrality by 2050 in line with the international commitments, including the 2030 National Determined Contribution (NDC) under the Paris Agreement (Council of the European Union, 2023).

Under the Gov. Reg., MS are mandated to report projections of national anthropogenic GHG emissions, providing valuable insights into how emissions may change over time. MS need to report their GHG projections by scenario, including information by gas, sector and year. The analysis of the time series of projections reported by MS shows significant differences by country, pointing to different drivers of emissions, as well as different impacts at country level (Figure 1).

Figure 1 Timeseries of percentage change of total emissions since 1990 by country.



Source: Authors using data reported by MS under the Governance Regulation

These projections are crucial for informed decision-making regarding national and European efforts to reduce GHG emissions. However, projections are estimates based on present emissions and assumptions about future activity drivers like Gross Domestic Product (GDP), population and energy prices. It is essential to periodically revise projections as knowledge evolves, as these provide estimates of future anthropogenic GHG emissions at certain points in time, not foretell the future.

The identification of drivers[1] of GHG emissions and their potential impact into different emission sources is of utmost importance to understand emissions trends and enhance methods and approaches to develop projections. Literature extensively explores the identification of proxies by means of decomposition analysis, regression techniques, and decoupling analysis examining the relationship between economic

[1] In this study, the words drivers and proxies are used interchangeably.

proxies and GHG emissions (Wang and Wang, 2020; Luo et al., 2017; Chen et al., 2018; Ahmad et al., 2017; Hashmi et al., 2020; Simionescu et al., 2021; Pao and Chen, 2020; Cohen et al., 2018; Wu et al., 2018).

A systematic literature review, conducted using Web of Science and keywords related to GHG projections and drivers, identified 140 relevant articles published in the last eight years. The scope of the analysis is of utmost importance in the selection and assessment of drivers. When only national GHG emissions are considered, national-level aggregated proxies are broadly identified, including Gross Domestic Product (GDP) and associated proxies (such as average income, Gross Value Added, or indicators such as GDP per capita), population, or consumer prices. Conversely, when studies cover sector-level emissions (in the context of IPCC Guidelines (2006): Energy, Industrial Process and Product Use- IPPU, Agriculture, Waste and Land Use, Land-Use Change and Forestry), different drivers are identified, including renewable energy, fuel prices, energy demand, and energy supply for energy; industrial activity levels for IPPU; livestock population and crop productivity for agriculture, and hectares covered by forest for LULUCF.

Going beyond, analysis at the emission source/sink level within each sector allows the identification of additional drivers addressing specifically the dynamics of the emissions source/sink. This allows the identification of proxies such as vehicle fleet for transport, soil carbon stocks for soil emissions, or household size for residential emissions. Relevant examples of studies identifying drivers national, sectoral, and source level emissions are identified in Zheng et al. (2019), Singh & Mukherjee (2019), Ozturk et al. (2016), and González-Sánchez & Martín-Ortega (2020).

This highlights the importance of selecting the right aggregation level for identifying the right drivers and for assessing the impact of the main factors affecting national and European emissions.

In this context, this study assesses the drivers reported by Member States in its projections to:

- Assess what proxies are reported by MS at the highest possible disaggregation level,
- Assess quantitatively how these proxies affect projections and what the differences are between countries,
- Based on the previous two points, propose a way to improve the quality controls made by the ETC CM into projections, and
- Propose additional proxies which are identified in the literature review and are not currently being considered by MS.

Complementary to the analysis of drivers of emissions, the assessment of policies and measures require a separate analysis. Climate and energy policy play an important role in influencing consumer preferences, market behaviours and technology innovation, but its impact on changes in GHG emissions varies across regions and policy types (McCurdy & Rhodes, 2023). Literature findings on the association between GHG emissions and policy variables diverge, with different studies showing that the relationship between GHG emissions and policy variables are negative, positive or non-existent (Demiral et al., 2021; Eskander & Fankhauser, 2020; Kim, 2021; Knill et al., 2012; Le Quéré et al., 2019). A summary of the methodologies and key findings of key literature in relation to the effects of climate and environmental policies on emissions is available in the table below.

Table 1 Summary of the empirical literature on the effects of climate and environmental policies on emissions.

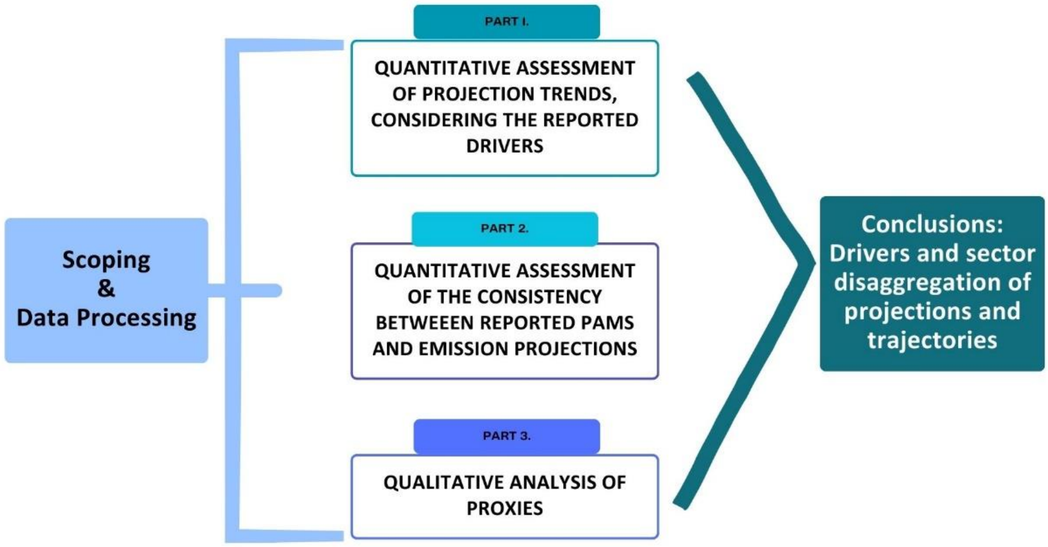
Research	Dependent Variable	Policy Variable	Other Explanatory Variables	Model Type	Findings
Eskander & Fankhauser (2020)	CO_2eq emissions per GDP unit	Stock of recent mitigation laws; stock of older mitigation laws	Economic activity variables; international trade; weather; rule of law; renewable energy potential	Panel data regression analysis	Passing a new climate law reduces annual CO_2 emissions, with the effect of laws becoming stronger in the longer term.
Le Quéré et al. (2019)	Total CO_2 emissions	Number of climate change policies adopted in a country	None	Spearman rank correlation test	Positive corelation is found between decrease in total emissions and the number of climate policy frameworks.
Knill et al. (2012)	CO_2, SO_2 and NO_X emissions per unit of GDP	Regulatory density (a measure of number of regulation); clean air policy intensity (a measure of regulatory strictness)	Economic activity variables; demographic variables; international trade; trade openness	Panel data regression analysis	Regulatory policy reduces emission intensities. However, an autoregressive model cast doubts on the causal relationship between changes in clean air policies and air pollutant emissions.
Neves et al. (2020)	CO_2 emissions per capita	Accumulated number of polices overtime	Economic activity variables; tax revenue; trade openness; RES policies; energy consumption variables	Dynamic regression model (estimating the short- and long-run effects)	Environmental regulation is effective in reducing CO_2 emissions.
Wang et al. (2021)	SO_2, smoke and water	Proportion of industrial pollution control investment in industrial added value; total investment in environmental governance; comprehensive utilisation rate of industrial solid waste; provincial pollution discharge fees	At the micro-level: sector's size of activity. At macro-level: economic activity variables; demographic variables	Fixed effects model and Generalized Method of Moments model	An inverted U-shaped relationship exists between environmental regulation and SO_2 emissions.
Hashmi & Alam (2019)	Total CO_2 emission	Environmentally related tax per capita; environmental patent counts	Economic activity variables; demographic variables; non-environmental patent counts	Panel fixed-effects, random-effects and Generalized Method of Moments models	In OECD countries, environmentally friendly patents and environmental tax revenue per capita are found to both be effective in reducing carbon emissions.
Demiral et al. (2021)	CO_2 emissions per capita	OECD environmental policy stringency (EPS) index	Industrialisation; trade openness; economic activity variables; energy productivity; international investment	Panel data regression analysis	Higher EPS leads to an increase in CO_2 emissions per capita for all sample, whereas the influence is statistically insignificant for the high income developed countries.
Frohm et al. (2023)	Sectoral CO_2 emissions	OECD environmental policy stringency (EPS) index	Economic activity variables; fossil fuel intensity	Panel data regression analysis	More stringent environmental policies are associated with lower emissions, that the effect builds over time and differs across sectors depending on their fossil fuel intensity.

This study builds on the literature, incorporating data on projections, drivers, and PaMs reported by MS. It aims to provide insights into the impact of proxies on sectoral GHG emissions, the influence of PaMs on GHG emission scenarios, and suggestions for enhancing the QA/QC cycle of projections and PaMs data under the Gov. Reg. 2018/1999.

3 Methodology

To unveil the trends of GHG emission among EU MS, the methodological framework is split in three parts (figure 2). The initial phase involves assessing the trends of GHG projections using the reported drivers. Subsequently, the second facet analyses the consistency of reported PaMs with GHG emission projections in the different scenarios. The third is dedicated to studying potential improvements in the reported drivers following a holistic perspective. Each part is further subdivided into methodological steps, establishing intricate connections among the three components.

Figure 2 Methodology framework.



Drawing from both the literature review and the collective experience of the ETC CM, the following describes the methodological framework for each of the parts.

3.1 Part 1. Quantitative assessment of projection trends, considering the reported drivers

The main objective of this component is to quantify differences in GHG emission trends among MS, accounting for variations in population size and economic development. The following approach is devised to attain this objective:

- Develop a methodology to assess the trends of the projections submitted by MS.
  - Using the parameters (proxies) reported by MS.
  - Standardising it for all individual MS and the EU-27.
  - Identifying improvements for the projections dataflow.
- Assess the trends using the information reported in the 2023.

The understanding of this component is therefore based on two fundamental assumptions. Firstly, GHG emission trends are analysed in conjunction with the parameters (proxies) that drive the evolution of the emissions. Secondly, the granularity of the analysis aims to be as disaggregated as possible, intending to analyse sectoral GHG emission trends and, when feasible, achieve a higher breakdown. This initial analysis does not account for the impact of PaMs on GHG emission trends, which is examined in a complementary manner in part 2 of the study.

3.1.1 Step 1: Determining Analysis Granularity

The primary aim of this step is to achieve the utmost granularity in the analysis, focusing on the most disaggregated IPCC category. This is essential for subsequent steps that aim to ascertain the optimal level of granularity for assessing drivers of GHG emissions and projections. The determination of granularity considers:

i. Data availability on GHG projections,
ii. Data availability on parameters (proxies) specific to the IPCC category,
iii. Differentiation between emission sources at the same level of disaggregation, where categories at the same level have different types of drivers for their GHG emissions, and
iv. Relevance to other EEA analyses.

For instance, if two IPCC sub-categories (e.g., 1A1 Energy Industries and 1A2 Manufacturing Industries) have theoretically different drivers, and the data allows for analysis, this granularity level is selected. Conversely, categories that are theoretically highly related or have scarce data are excluded unless there is EEA relevance.

The pursuit of the highest granularity level enhances completeness, providing a comprehensive understanding of possibilities for improving the analysis. A finer granularity allows for a more profound analysis of intricate dynamics, facilitating a robust evaluation of potential study enhancements.

By emphasising the pursuit of the highest level of granularity, the overarching goal is to illustrate that a specific set of proxies effectively explains the emissions patterns of GHG emissions. This strategic approach is designed to enable a more profound analysis, allowing for the aggregation to the sectorial level based on the identified proxies, rather than being confined to studying only the available data at a particular granularity level.

3.1.2 Step 2: Selecting Relevant Parameters (Proxies)

To guide parameters selection (proxies), the following essential criteria are considered:

- Parameters/proxies must have a theoretical foundation for explaining the GHG emissions for the selected category/sector.
- In terms of data availability, a minimum threshold is set, considering a proxy reported by at least 70% of the sample.

Meeting these conditions is required for a first selection of proxies by IPCC category, therefore for the emission sources selected in step 1. The first difference (natural logarithms) of the selected proxies undergoes the Augmented Dickey Fuller test (ADF) to ensure the time series is non-stationary. Non-stationarity is vital for assessing proxy impact on GHG emissions by IPCC category, often achieved by taking the first difference of reported time series, except in the presence of significant data issues.

To avoid relationship between regressors, variables are then tested for multicollinearity. In case variables show multicollinearity, the proxy possessing the highest explanatory power is selected. This process determines the most relevant proxies for empirical testing by IPCC category.

3.1.3 Step 3: Empirical Assessment of Proxies

This step involves evaluating the empirical impact of selected proxies on GHG emissions by IPCC category (Step 1 and 2). It is aimed to determine whether projections either overestimate or underestimate the influence of a given proxy in light of its statistical behaviour. The variations among different countries in terms of proxy impact is explored in this step as well.

Simple regression analysis is employed to assess the elasticities[2] of the different parameters, allowing for a simplified model to link GHG emissions and the parameters, akin Cohen et al. (2018). The model considered is:

$$y_{i,t} = \sum_{k=1}^{K} \beta_k \cdot x_{i,k,t} + u_{i,t}$$

where *y* is the GHG emissions of country *i* (*i = 1,…,N*) for year *t* (*t = 1,…,T*); *x* is a *k* regressor (*k = 1,…,K*) or potential explanatory factor.

This analysis is conducted by country for proxies identified by IPCC category to achieve the assessment's objectives.

3.1.4 Step 4: Estimating the temporal profile of drivers for sectoral GHG emissions

Complementary to Step 3, the final step involves assessing differences in different time periods (assessment of differences in trends) and between MS. When the elasticities of parameters in the projected period differ substantially from the historical period, it suggests that projections are either significantly affected by PaMs (link part 2) or that projections are over/underestimated due to the evolution considered for the parameter.

3.2 Part 2. Quantitative assessment of the consistency between reported PaMs and emission projections

This component aims to assess whether the reported WEM and WAM projections are aligned with expected emissions trajectories, accounting for existing and additional PaMs using estimated projections until 2030. The process involves defining the relationship between GHG emissions and PaMs, selecting indicators, and establishing an empirical model for testing.

3.2.1 Step 1. Defining the relationship between GHG emissions and PaMs

To analyse the relationship between GHG emissions and PaMs, an econometric model is developed. The model's foundation includes defining indicators for both GHG emissions and PaMs.

For GHG emissions, comprehensive country-level data from 2000 to 2020 serves as the foundation of the analysis, as reported by MS to the UNFCCC and EU GHG Monitoring Mechanism. This dataset, in terms of CO_2 equivalent, defines the dependent variable.

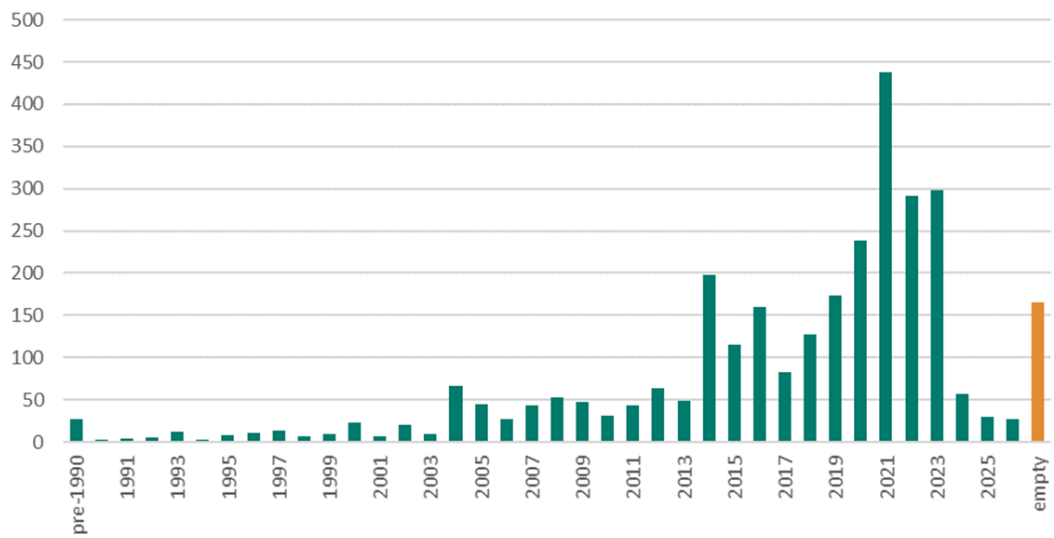
Relevant indicators for PaMs are identified using data reported to the European Environment Agency (EEA) by MS under the Governance Regulation 2018/1999. These include information on integrated climate and energy PaMs (year of implementation, target sector, and climate and energy dimension, among others),

2 Understood as the change in GHG emissions in relation movements of that proxy.

covering both expired/implemented and planned/adopted measures. However, there is a lack of completeness in reporting PaMs effects, mainly due to the challenges in measuring ex post policy outputs. The model defines explanatory variables for PaMs to assess their short and long-term impact, in line with methodologies observed in literature (Eskander & Fankhauser, 2020; Neves et al., 2020), considering that the effects of policies are expected to increase over time. The model also includes control variables for economic factors, such as GDP per resident.

This study analyses annual data for the EU-27 from 2000 to 2020, chosen for data availability across all countries. The adoption of climate and energy PaMs intensified post-2000 (Figure 3) in line with the European Community's commitments to the Kyoto Protocol, making this period most relevant for assessing PaMs effectiveness in driving changes in GHG emissions.

Figure 3 Number of single PaMs reported by EU MS per implementation year.



Source: Dauwe et al., 2023.

Selecting the indicator for GHG emissions

GHG emissions are analysed by IPCC sector categories as follows:

- 1.A.1 Energy Industries,
- 1.A.2 Manufacturing Industries and Construction,
- 1.A.3 Transport,
- 1.A.4 Other Sectors (commercial/institutional, residential, agriculture/forestry/fishing),
- 2. Industrial Processes and Product Use (IPPU),
- 3. Agriculture,
- 4. Land Use, Land-Use Change and Forestry (LULUCF), and
- 5. Waste.

Sector granularity considers data availability for explanatory variables, as from Part 1.

Table 2 Share of sectors' GHG emissions from total GHG emissions for all countries over the period 2000-2020.

GHG Sector	Share from total GHG emissions
1.A.1 Energy Industries	31.9%
1.A.2 Manufacturing Industries and Construction	13.0%
1.A.3 Transport	21.4%
1.A.4 Other Sectors	15.8%
2. IPPU	9.8%
3. Agriculture	10.2%
4. LULUCF	-8.3%
5. Waste	3.6%
Total	**97%**

Source: Authors' estimates based on national emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism (EEA, 2023).

These eight sectors collectively contribute to 97% of total GHG emissions in the EU-27 during the analysed period, highlighting their significant relevance. Almost all sectors account for a share of at least 10% in total emissions, with Energy Industries and Transport being the largest contributors, and waste sector the smallest with a share of 3.6%.

The dependent variable in the model is the total annual GHG emissions level $CO2eq$ measured in ktCO_2-eq .

Selecting the PaMs indicators

Due to differences in the specification of IPCC sectors and the target sectors of reported PaMs under the Governance Regulation, the GHG sectors are paired with PaMs sectors to align both (Table 4).

Table 3 Pairing of GHG sectors with PaM target sectors.

GHG Sector	PaMs Sector
1.A.1 Energy Industries	Energy supply & Energy consumption
1.A.2 Manufacturing Industries and Construction	Energy consumption
1.A.3 Transport	Transport
1.A.4 Other Sectors	Energy consumption
2. IPPU	Industrial processes
3. Agriculture	Agriculture
4. LULUCF	LULUCF
5. Waste	Waste management/waste

A nuanced approach is necessary in paring sectors as some links are not straightforward. For instance, PaMs targeting energy consumption in the residential, commercial, and manufacturing sectors impact the

GHG trajectory of the energy industries. This necessitates consideration of PaMs in both 'energy consumption' and 'energy supply' sectors. In the transport sector, the influence of PaMs on energy industries' GHG emissions is limited, except in cases of electrification policies. Due to this, the pairing of transport target sector with energy industries' GHG emissions is excluded to maintain analytical clarity.

Granular distinctions in PaMs sectors pose challenges, especially when targeting energy consumption across multiple GHG sectors. Harmonization issues in defining GHG and PaMs sectors further complicate pairing, but this is expected to introduce marginal noise into the analysis.

The considered PaMs are those contributing to the three dimensions 'Decarbonisation: GHG emissions and removals,' 'Decarbonisation: Renewable energy,' and 'Energy efficiency'. Those contributing to 'Research, innovation and competitiveness,' 'Internal energy market,' and/or 'Energy security' are excluded for their likely disparate impact on GHG emissions in terms of magnitude and timing.

Post-implementation, PaMs are expected to impact emissions immediately or gradually. Therefore, the model aggregates annual effects, considering short-term effects with a three-year lag (*PAMst*) and long-term effects with a cumulative approach (*PAMlt*) beyond three years. This accounts for the varied effectiveness of PaMs over time, aligning with established literature (Eskander & Fankhauser, 2020; Knill et al., 2012; Neves et al., 2020). The focus is on capturing short-term impacts from PaMs implemented in the previous three years and long-term effects from the cumulative stock of PaMs implemented beyond three years, irrespective of expiration. This approach acknowledges that the effects of fiscal or regulatory policies endure beyond the implementation period, reflecting structural changes and the time required for technology/system integration.

Defining the model

Control variables are essential in assessing the impact of climate and energy PaMs on GHG emissions. Economic activity, as represented by real GDP per capita (*GDPpc*), is a key factor linked to emission changes. Eurostat data on annual real GDP and population count are utilised to estimate *GDPpc* for each country (Eurostat, 2023a; Eurostat, 2023b).

This model opts for simplicity and uses only one control variable. To prevent potential multi-collinearity, *GDPpc* is singularly used as a control variable. Moreover, the need for future projections of all exploratory variables for every country imposes constraints on variable selection.

The regression model, constructed by converting GHG emissions and *GDPpc* time series into natural logarithmic form (*ln*), includes a regression constant (α), coefficients (β and γ), and an error term (ε). The final equation is formulated as follows, where β and γ are estimated through ordinary least squares (OLS) method:

$$lnCO2eq_{i,s,t} = \alpha + \beta_1 PAMst_{i,s,t} + \beta_2 PAMlt_{i,s,t} + \gamma lnGDPpc_{i,s,t} + \varepsilon_{i,s,t}$$

This model is applied separately for each country *i* and each sector *s*, and the estimation is conducted using the OLS method.

3.2.2 Step 2. Estimating emission projections for the period 2021-2030 based on the determined relationships.

Using the estimated relationships, the next step involves projecting emissions for 2021-2030 based on country-specific data for *PAMst, PAMlt,* and *GDPpc.* These projections, referred to as 'estimated projections', encompass both the WEM and WAM scenarios. Data primarily relies on Member States' submissions under Governance Regulation 2018/1999.

GDP and population inputs are based on country-reported projections. Linear interpolation is applied for five-year interval data, while missing GDP projections are supplemented using the European Commission's growth rate projections up to 2024 (Directorate-General for Economic and Financial Affairs, 2023), followed by linear progression towards a 2% annual growth rate reached by 2030.

3.2.3 Step 3. Assessment of consistency between reported projections and PaMs

Aligned with the study's objectives, reported projections by MS then undergo consistency assessments concerning reported PaMs.

In the first check, the estimated projections are used to assess whether reported WEM and WAM projections align with expected emissions trajectories, factoring in PaMs effects. This entails evaluating annual levels and overall trajectory consistency.

In the second check, discrepancies between reported emissions levels in WAM and WEM scenarios are examined for alignment with reported planned PaMs. 'Planned PaMs' refer to new WAM scenario PaMs for 2021-2030. Differences between WAM and WEM scenarios are expected to correspond to reported planned PaMs in the WAM scenario.

A selection of countries illustrates how these checks can be performed, providing insights into the findings yielded by such assessments.

3.3 Part 3. Qualitative analysis of proxies

The main goal of Part 3 is to gain a better understanding of the underlying assumptions and inputs used to develop activity drivers for estimating GHG emission projections. It focuses on qualitatively assessing included and excluded drivers in GHG projections, and those drivers currently excluded but bearing significant potential impact. The primary objectives are twofold. Firstly, to analyse reported activity drivers for selected MS to gauge reporting completeness and quality. Secondly, to identify key variables for future GHG emissions reporting through desk research.

Research questions that this subtask aims to answer, based on the mentioned objectives, include: What methodologies and variables are used to develop activity drivers? What is the nature of these drivers, and are there any similarities between the selected MS? What is the impact of the developed activity drivers on GHG projections? What data inputs (and from which sources) are used to develop activity drivers, and are there any missing ones that need consideration in future GHG projections?

To achieve these objectives, the following tasks are developed:

1. Selection of MS (good balance): MS selection is based on the input attained from this task group (Part 1 and Part 2), aiming for good balance of diversities in terms of location, economic size, maturity, etc.
2. Going through methodology reports: Reviewing methodology reports prepared by the selected MS explaining how they reported GHG projections in 2023.
3. Reviewing National Energy and Climate Plans (NECP): Reviewing NECP methodology reports of the selected MS to identify similarities and/or differences of used drivers.

4. Literature review of relevant drivers: Identifying drivers that might be of interest to consider in addition to/instead of ones currently used, in consideration of drivers identified in Part 1 and Part 2.

4 Results and Discussion

In this section, the results obtained are discussed in detail for the three components of the methodological framework.

4.1 Part 1. Quantitative assessment of projection trends, considering the reported drivers

4.1.1 Step 1: Determining Analysis Granularity

In this phase, the main goal is a detailed analysis, aiming for a thorough understanding of GHG emission factors. The selection of sectors underwent a meticulous process, focusing on key categories essential for understanding GHG dynamics.

Analysing the GHG Projections dataflow for 2023 revealed uneven MS projections reporting. At the IPCC sector level, all MS reported projections for the main GHGs and total emissions.

At the category level, IPCC categories under sector 2, and several categories within all sectors, showed incomplete reporting for projections [1B (25 out of 27) and 1C (2 out of 27), 3C (9 out of 27), 3E (2 out of 27), 3F (13 out of 27), and 3I (10 out of 27), 4F (17 out of 27), 4H (3 out of 27), and 5C (22 out of 27)].

At the sub-category level, reporting had more gaps. Energy sector sub-categories (1A1, 1A2, 1A3, 1A4) showed complete reporting from all MS, while 1A5, 1B1, 1B2 had several missing MS (17, 14, and 23 out of 27, respectively). For other sectors, only 2A1 (21 out of 27) and 2C1 (17 out of 27) are reported.

At the activity level, reported projections are limited to the energy sector, with activities 1A3a & 1A3b (27 out of 27), as well as 1A4a, 1A4b & 1A4c (26 out of 27), and 1A1a (25 out of 27) showing the most complete reporting. Table 1, extracted from the Analysis of MS' 2023 GHG projections report, displays MS reporting by gas.

Table 4 Completeness of reporting on GHG emissions in the 2023 cycle.

Category	CO2	N2O	CH4	HFC	PFC	Unspecified	SF6	NF3	Total	ETS	ESR
1. Energy	27	27	27	1	1	1	1	1	27	27	27
1.A. Fuel combustion	27	27	27	1	1	1	1	1	27	27	27
1.A.1. Energy industries	27	27	27	1	1	1	1	1	27	27	27
1.A.1.a. Public electricity and heat production	26	25	25	0	0	0	0	0	25	25	25
1.A.1.b. Petroleum refining	20	19	18	0	0	0	0	0	19	19	19
1.A.1.c. Manufacture of solid fuels and other energy industries	21	21	21	0	0	0	0	0	21	18	21
1.A.2. Manufacturing industries and construction	27	26	26	0	0	0	0	0	27	26	27
1.A.3. Transport	27	27	27	1	1	1	1	1	27	13	27
1.A.3.a. Domestic aviation	27	27	27	0	0	0	0	0	27	0	23
1.A.3.b. Road transportation	27	27	27	0	0	0	0	0	27	7	27
1.A.3.c. Railways	25	25	25	0	0	0	0	0	25	7	25
1.A.3.d. Domestic navigation	26	26	26	0	0	0	0	0	26	7	26
1.A.3.e. Other transportation	16	16	16	0	0	0	0	0	16	12	16
1.A.4. Other sectors	27	26	26	0	0	1	0	0	27	18	27
1.A.4.a. Commercial/Institutional	26	25	25	0	0	0	0	0	26	16	26
1.A.4.b. Residential	26	25	25	0	0	0	0	0	26	6	26
1.A.4.c. Agriculture/Forestry/Fishing	26	25	25	0	0	0	0	0	26	10	26
1.A.5. Other	17	16	15	0	0	0	0	0	17	6	17
1.B. Fugitive emissions from fuels	25	18	25	0	0	0	0	0	25	15	25
1.B.1. Solid fuels	9	1	13	0	0	0	0	0	14	8	14
1.B.2. Oil and natural gas and other emissions from energy production	23	15	23	0	0	0	0	0	23	11	23
1.C. CO2 transport and storage	1	1	1	0	0	0	0	0	2	2	2
2. Industrial processes	27	27	17	27	21	3	26	7	27	26	27
2.A. Mineral Industry	26	1	1	0	0	0	0	0	26	25	22
2.A.1. Cement production	21	1	1	0	0	0	0	0	21	20	7
2.B. Chemical industry	21	18	13	4	3	1	2	1	22	18	20
2.C. Metal industry	21	1	13	4	11	0	2	1	22	19	19
2.C.1. Iron and steel production	17	0	10	1	1	0	1	1	17	16	12
2.D. Non-energy products from fuels and solvent use	26	3	3	0	1	0	0	0	26	5	26
2.E. Electronics industry	1	0	1	7	8	1	7	7	12	3	12
2.F. Product uses as substitutes for ODS (8)	1	0	1	27	11	1	0	1	27	3	27
2.G. Other product manufacture and use	5	24	3	3	2	0	26	0	27	4	27
2.H. Other	5	2	1	2	1	1	1	0	8	5	8
3. Agriculture	26	27	27	1	1	1	1	1	27	0	27
3.A. Enteric fermentation	1	1	27	0	0	0	0	0	27	0	27
3.B. Manure management	1	26	27	0	0	0	0	0	27	0	27
3.C. Rice cultivation	1	1	8	0	0	0	0	0	9	0	9
3.D. Agricultural soils	1	26	0	0	0	0	0	0	26	0	26
3.E. Prescribed burning of savannahs	1	0	0	0	0	0	0	0	2	0	2
3.F. Field burning of agricultural residues	1	12	12	0	0	0	0	0	13	0	13
3.G. Liming	24	0	0	0	0	0	0	0	24	0	24
3.H. Urea application	25	0	0	0	0	0	0	0	25	0	25
3.I. Other carbon-containing fertilizers	9	0	0	0	0	0	0	0	10	0	10
3.J. Other (please specify)	0	1	1	0	0	0	0	0	2	0	2
4. Land Use, Land-Use Change and Forestry (LULUCF, reported emissions and removals) (9)	27	27	24	0	0	0	0	0	27	0	0
4.A. Forest land	27	23	21	0	0	0	0	0	27	0	0
4.B. Cropland	27	27	13	0	0	0	0	0	27	0	0
4.C. Grassland	27	24	17	0	0	0	0	0	27	0	0
4.D. Wetlands	26	19	9	0	0	0	0	0	26	0	0
4.E. Settlements	27	25	3	0	0	0	0	0	27	0	0
4.F. Other Land	16	15	1	0	0	0	0	0	17	0	0
4.G. Harvested wood products	25	0	0	0	0	0	0	0	25	0	0
4.H. Other	1	1	1	0	0	0	0	0	3	0	0
5. Waste	21	27	27	0	0	0	0	0	27	1	27
5.A. Solid Waste Disposal	1	1	27	0	0	0	0	0	27	0	27
5.B. Biological treatment of solid waste	1	26	26	0	0	0	0	0	27	0	27
5.C. Incineration and open burning of waste	19	21	19	0	0	0	0	0	22	1	23
5.D. Wastewater treatment and discharge	1	26	26	0	0	0	0	0	26	0	26
5.E. Other (please specify)	1	1	3	0	0	0	0	0	4	0	5
CO2 captured	3	0	0	0	0	0	0	0	4	1	1
CO2 emissions from biomass	14	0	0	0	0	0	0	0	14	0	1
IB.Aviation	23	22	22	0	0	0	0	0	23	0	1
IB.Navigation	20	18	19	0	0	0	0	0	20	0	1
Indirect CO2 (if available) (10)	5	0	0	0	0	0	0	0	6	0	6
International bunkers	21	20	20	0	0	0	0	0	20	0	1
Memo items	3	3	3	0	0	0	0	0	4	0	0
Total excluding LULUCF	27	27	27	27	21	4	26	10	27	27	27
Total including LULUCF	27	27	27	27	21	4	26	10	27	26	26

Source: Analysis of MS' 2023 GHG projections Submitted under Art 38 (1)(b) of the Regulation on the Governance of the Energy Union and Climate Action (EU) 2018/1999

From this analysis, most sectors and categories were selected for the empirical testing, with exceptions in sector 2 IPPU and sector 4 LULUCF due to incomplete reporting. Categories within sectors like IPPU, Agriculture, and Waste, experiencing reporting gaps, were excluded from empirical testing.

Further disaggregation considered only energy sector sub-categories and activities, emphasising EEA relevance, complete reporting levels and proxy availability for empirical testing. Sectors and sub-categories filled through gap-filling were disregarded, ensuring inclusion of only MS-reported sectors and categories without ETC CM intervention.

These considerations resulted in a granularity level comprising five key sectors and four sub-categories for sector 1, outlined as follows:

1. Energy
   1A1. Energy Industries
   1A2. Manufacturing Industries
   1A3. Transport
   1A4. Others
      1A4a. Commercial/Institutional
      1A4b. Residential
2. IPPU
3. Agriculture
4. LULUCF
   4A. Forest Land
   4B. Cropland
   4C. Grassland
   4D. Wetlands
   4E. Settlements
   4G. Harvested Wood Products
5. Waste
   5A. Solid Waste Disposal
   5D. Wastewater treatment and discharge.

This granularity level guided the subsequent methodological steps.

4.1.2 Step 2: Selecting Relevant Parameters (Proxies)

In the evaluation of GHG emission trends, meticulous parameter selection is essential to mitigate omitted variables bias, especially in the absence of randomisation. Consequently, prior to embarking on empirical analysis, the parameters were meticulously chosen based on their theoretical relevance to GHG sectoral emissions and their availability within the GHG Projections dataflow.

In the initial phase of proxy selection, a theoretical framework guided the assessment, considering the potential correlation between parameters and GHG emission trends. The theoretical relation is rooted in the understanding that one or more parameters may exhibit correlation with a specific sector in theory, thereby influencing its GHG emissions. For example, the emissions from the industrial sector, resulting from the use of fossil fuels, can be explored using GDP as a proxy. This rationale stems from the industry's reliance on fossil fuels as a fundamental input for production, ultimately contributing to economic outputs reflected in GDP. Thus, this preliminary selection was driven by conceptual correlations. The subsequent empirical design outlined in the following sections, investigates the correlation between the parameters and GHG emissions by sector, validating and refining the theoretical relationships.

The analysis considered 343 proxies/sub-parameters reported by MS. However, only proxies reported by over 70% of EU-27 MS were analysed. Proxies with data gaps filled by ETC CM were excluded. Refer to Annex 1 for the full list of 343 sub-parameters/proxies and reporting details.

Despite the high number, most proxies are reported by one or few MS, hindering empirical analysis and cross-country comparisons. Moreover, relevant proxies were absent for some IPCC categories, limiting further disaggregation. Note that numerous parameters are not proxies but are used in projections. While informative for GHG projection results, they do not explain GHG drivers. Examples include Managed cropland-Cropland remaining cropland.

The table below displays the initial selection of proxies by IPCC category for empirical testing.

Table 1 Selection of proxies by IPCC category (>70% reporting rate).

IPCC categories	Proxies							
1								
1A1	Population	International (wholesale) fuel import prices-Natural gas	Final energy consumption - All sectors-Total	Gross inland consumption by fuel type source-Natural gas Gross inland consumption by fuel type source-Oil Gross inland consumption by fuel type source-Renewables	Gross electricity generation-Total Gross electricity generation-Renewables Gross electricity generation-Natural gas	EU ETS carbon price	International (wholesale) fuel import prices-Coal International (wholesale) fuel import prices-Crude Oil	Gross domestic product-Constant prices
1A2	Final energy consumption - Industry-Total	Final energy consumption - Industry-Natural gas	EU ETS carbon price	Gross domestic product-Constant prices				
1A3	Population	Final energy consumption - Transport-Oil	Final energy consumption - Transport-Total	Gross domestic product-Constant prices				
1A4	Population	Final energy consumption - Tertiary-Total	Gross domestic product-Constant prices					
1A4a	Population	Final energy consumption - Tertiary-Total	Gross domestic product-Constant prices					
1A4b	Population	Number of households	Final energy consumption - Residential-Total					
1A4c	Final energy consumption - Agriculture and Forestry-Total	Gross domestic product-Constant prices						
2	EU ETS carbon price	Gross domestic product-Constant prices						
3	Livestock-Dairy cattle	Livestock-Non-dairy cattle	Gross domestic product-Constant prices					
3A	Livestock-Dairy cattle	Livestock-Sheep	Livestock-Non-dairy cattle	Livestock-Pig	Livestock-Poultry			

IPCC categories	Proxies				
3B	Livestock-Dairy cattle	Livestock-Non-dairy cattle	Nitrogen input from application of manure	Livestock-Poultry	
3D	Nitrogen input from application of synthetic fertilizers	Area of cultivated organic soils			
4	Afforested land-Cropland converted to forest land	Deforested land-Forest land converted to settlements			
4.A.	Managed forest land-Forest land remaining forest land				
4.B.	Managed cropland-Cropland remaining cropland	Afforested land-Cropland converted to forest land			
4.C.	Managed grassland-Grassland remaining grassland				
4.D.					
4.E.	Deforested land-Forest land converted to settlements				
4.F.					
4.G.					
5	Population	Municipal solid waste (MSW)-Landfills			
5A	Municipal solid waste (MSW)-Landfills				
5D	Population				

4.1.3 *Step 3: Empirical Assessment of Proxies*

In the third step, after determining the granularity level and selecting relevant proxies, the analysis assessed how these chosen proxies influenced sectoral GHG emissions across various time periods, spanning from 2021 to 2050 as reported in MS projection scenarios. The study also investigated variations in proxy impact across different countries.

The chosen econometric model employed a linear regression equation {1}, estimated using the ordinary least squares (OLS) method. This model aimed to explore the relationship between a country's GHG emissions and potential explanatory proxies. Statistical tests were integrated for optimal parameter selection, and the analysis results are presented below.

The initial proxy selection was based on the theoretical relationship between proxies and IPCC categories, retaining those reported by 70% or more of the participating MS. Following this, the time series underwent testing for stationarity and multicollinearity, as the presence of these issues could affect the analysis.

The ADF test assessed the presence of a unit root in an autoregressive model, indicating non-stationarity. The objective was to assess whether the time series exhibits time-dependent structure, thereby rejecting the notion of stationarity or trend stationarity in the elasticities of the selected parameters. In practical terms, various p-values were utilised, with thresholds of 10, 5, and 2, corresponding to critical values for statistical significance at 90%, 95%, and 98%, respectively.

Subsequently, the variance inflation factor (VIF) was used to test multicollinearity, indicating the level of correlation among independent variables in a multiple regression model. Multicollinearity arises when there is a correlation among multiple independent variables in a multiple regression model, distorting the accuracy of the regression results.

In the presence of multicollinearity, the proxy with a higher elasticity value (higher parameter value obtained through OLS) was selected. The ADF and VIF tests refined the identification of proxies, ensuring that time series with stationarity or multicollinearity issues were not used for trend assessment.

The final selection of proxies by IPCC category, after statistical testing, resulted as follows:

- 1A1. Gross domestic product-Constant prices, EU ETS carbon price
- 1A2. EU ETS carbon price, Gross domestic product-Constant prices
- 1A3. Gross domestic product-Constant prices
- 1A4. Gross domestic product-Constant prices
- 1A4a. None*
- 1A4b – None*
- 1A4c – None*
- 2. Gross domestic product-Constant prices
- 3. Gross domestic product-Constant prices
- 3A. Livestock-Poultry
- 3B. Livestock-Poultry
- 3D – None*
- 4 – None*
- 5 – None*

* *“None”* reflects cases where no proxies with non-stationarity data were found in the reported data, preventing empirical testing in that category.

It is important to note that differences in reporting from MS impedes obtaining values for all IPCC categories and proxies for all countries.

The following tables (Table 6 – 9) depict the elasticities of the identified proxies by IPCC category after statistical testing. The use of log-log data in equation {1} allows to interpret the results of the parameters (β_k) as elasticities, representing the impact in one variable as a result of a variation in the other.

Table 5 Elasticities by proxy and country – category 1A1 Energy Industries

CountryCode	Gross domestic product-Constant prices	EU ETS carbon price
SE	-1.14	-0.39
PL	-1.44	-0.80
CZ	-3.85	-1.72
BG	0.16	-1.91
LV	-2.54	-1.23
ES	-0.56	-0.18
NL	-6.40	-0.89
EL	-2.32	-0.95
DE	-6.25	-2.51
PT	-5.37	0.00
HR	-0.71	-0.28
EE	-8.27	-1.74
AT	-1.22	-0.41
Average	-3.07	-1.00

Examining the table above yields several valuable insights. In the case of 1A1 projections, the modelled EU average impact of the EU-ETS carbon price is -1. However, noteworthy variations are observed among individual MS, with Germany, Estonia, or Bulgaria projecting a considerably higher impact than other MS. These highlights potential inconsistencies in the proxy used for their projections. On the contrary, when it comes to the GDP proxy, the EU average impact stands at -3.07[3], with Estonia, the Netherlands and Germany exhibiting significant deviations in their values, which indicates substantial differences. Similar analysis can be developed with the results provided for other proxies and categories in the following tables.

This type of analysis could be considered for incorporation in the regular QA/QC checks of projections, aiming at assessing the impact and quality of the proxies reported.

[3] The interpretation of elasticities should be as follows: A 1% increase in the EU ETS carbon price is associated with a 3.07% decrease in GHG emissions. Conversely, a 1% decrease in the EU ETS carbon price would theoretically be associated with a 3.07% increase in GHG emissions.

Table 6 Elasticities by proxy and country – category 1A2 Manufacturing Industries and construction.

Country code	EU ETS carbon price	Gross domestic product-Constant prices
SE	-0.62	-1.60
LT	-0.95	-0.95
PL	-0.31	-0.53
DK	-1.42	-4.34
CZ	-0.04	-0.10
BG	-0.15	0.01
IT	-0.06	-0.84
IE	-0.27	-0.28
CY	-0.31	-0.60
LV	-0.65	-1.02
ES	-0.08	-0.22
NL	-0.36	-1.31
EL	-0.30	-0.71
DE	-1.42	-4.05
PT	0.00	0.04
HR	-0.23	-0.57
EE	0.08	0.44
RO	0.34	0.57
AT	0.09	0.26
Average	-0.35	-0.83

Table 7 Elasticities by proxy and country – categories 1A3 Transport, 1A4 Other, Industrial Processes and Product Use, and 3 Agriculture.

Country code	1A3 Gross domestic product-Constant prices	1A4 Gross domestic product-Constant prices	2 Gross domestic product-Constant prices	3 Gross domestic product-Constant prices
SE	-3.41	-1.44	-1.46	-0.25
LT	-2.73	-0.34	-0.82	-0.38
PL	-0.02	-0.22	-0.07	0.00
DK	-3.56	-2.21	-0.89	-0.37
CZ	-0.99	-0.95	-0.44	-0.26
BG	0.01	0.01	0.01	-0.01
IT	-0.86	-1.04	-0.14	-0.43
IE	-0.85	-0.59	0.15	0.01
CY	-4.55	-0.42	0.14	-0.05
LV	-1.35	-1.35	-0.12	-0.07
ES	-0.12	-0.75	-3.19	-0.28
NL	-1.68	-1.65	-2.70	-0.16
EL	-0.63	-0.90	-0.18	0.61
FI	-3.22	-3.91	-1.34	-0.64
DE	-6.27	-4.57	-3.44	-0.36
PT	-3.48	-0.93	-1.08	0.05
HR	-1.08	-0.32	-0.57	-0.17
EE	-3.80	-0.13	-1.42	0.19
RO	0.95	0.36	-0.24	-
LU	-1.02	-1.02	0.07	-0.03
AT	-2.61	-1.13	-0.23	-0.29
Average	-1.97	-1.12	-0.86	-0.14

Table 8 Elasticities by proxy and country – categories 3A Enteric fermentation and 3B Manure management.

Country code	3A Livestock-Poultry	3B Livestock-Poultry
SE	-0.42	-
LT	-2.92	-
PL	0.14	0.30
DK	1.12	3.40
CZ	0.21	0.47
BG	0.93	0.93
IT	-6.32	-
IE	-0.36	-0.34
CY	-0.06	0.06
LV	-	-
ES	1.72	1.74
NL	0.00	0.00
EL	1.00	1.00
FI	1.71	6.55
DE	-6.25	-6.93
SI	0.00	0.00
PT	0.21	5.36
HR	-1.45	0.36
BE	-2.62	-0.54
EE	0.07	0.05
MT	0.05	0.49
FR	-0.50	0.17
LU	0.03	-0.10
AT	0.25	0.31
SK	-0.05	0.31
Average	-0.56	0.65

Since the reported proxies lack historical data, the elasticity values obtained have not been put into the context of past trends. Despite this limitation, delving into historical trends can provide valuable insights into the quality of projections, and it should be further explored.

For the selected IPCC categories outlined in Step 2, the statistical analysis did not identify any proxies. This was primarily attributed to reporting gaps or the non-stationarity of the data. The results obtained demonstrate the numerous proxies reported are non-stationary.

If all the projected series of the proxies were non-stationary, this will have several implications (Ryan, Haslbeck, & Waldorp, 2023):

- **Non-stationary relationship**: Signals that variable (e.g., GDP, population) evolve inconsistently over time, introducing uncertainty to projections.
- Increased uncertainty in projections: Projecting onto non-stationary variables may mean that past trends will not hold in the future. This can hinder the accuracy of predictions and amplify uncertainty in estimates of GHG emissions (GHG).
- **Structural Break Analysis**: Identifies points in time where relationships between variables significantly changes, aiding in model adjustments. Understanding these structural breaks can help in calibrating models to better accommodate shifts in relationships.
- **Higher sensitivity to proxy changes**: Non-stationary projections may be more sensitive to slight changes in proxy variables (e.g. GDP, population, etc.), excreting significant impacts on GHG emissions projections.
- **Need to consider adjustments or additional variables**: Addressing non-stationarity may involve employing modelling techniques that consider the possibility of changes in

relationships between variables over time. Exploring the inclusion of other proxies that could affect GHG emissions could enhance the accuracy of projections.

When dealing with non-stationary time series data, some beneficial modelling techniques can be (Castle, Doornik, & Hendry, 2020):

- **Time Series Decomposition**: Breaking down the time series data into its individual components like trend, seasonality, and noise. Understanding these components separately, eases to study the underlying patterns and changes in relationships over time.
- **Cointegration Analysis**: Aids multiple non-stationary time series that share a long-term relationship. It helps identify the underlying relationships between variables that move together in the long run, despite short-term fluctuations.
- **Vector Autoregression (VAR) Models**: Captures independencies between multiple interacting time series variables. This means that when there are multiple time series variables that interact with each other, VAR models consider the interdependencies between these variables and how changes in one variable can affect others over time.
- **Machine Learning Techniques**: Algorithms like Random Forests, Gradient Boosting, or Neural Networks, equipped to handle non-stationary by learning from historical patterns. These capture complex relationships between variables and potentially handle non-stationary data.

Considering these implications, exploring advanced modelling techniques and conducting structural break analyses can enhance the robustness and reliability of GHG emission projections.

4.1.4 Step 4: Estimating the temporal profile of drivers for sectoral GHG emissions

To comprehensively evaluate trends over diverse time spans and disparities among countries, an in-depth analysis was conducted on the parameters that successfully passed the statistical testing. This investigation unfolded across two dimensions: (i) examining variations across different time periods, and (ii) probing differences among countries. To achieve this objective, equation {1} was employed, delineating four distinct timeslots: 2021 (the reference year), 2021-2030, 2030-2040 and 2040-2050. This analysis focused on proxies by IPCC category that met the criteria established in Step 3.

The following table shows the results of the assessment for category 1A1, for the proxy Gross domestic product-Constant prices.

Table 9 Temporal evolution for the elasticity of GDP on the GHG emissions of category 1A1.

Country code	2021	2021-2030	2030-2040	2040-2050
SE	0.04	-0.18	-2.17	0.00
PL	-0.38	-0.37	-2.77	0.00
CZ	1.72	2.09	-2.86	-0.11
BG	0.12	0.29	-9.93	0.00
LV	0.08	-0.47	-2.94	-0.03
ES	-0.26	0.19	-1.38	0.00
NL	0.71	-2.47	-1.00	-0.01
EL	2.79	-1.13	-1.10	0.00
DE	1.50	0.59	-4.13	0.01
PT	1.45	-2.63	-2.30	-0.02
HR	0.17	0.21	-0.90	-0.01
EE	0.13	0.60	-1.37	-0.01
AT	0.31	0.50	-0.65	0.00

Variations are observed both within a specific MS across different years and across various MS for a given year. The interpretation of elasticity highlights that a 1% change in GDP results in a percentage change impact on GHG emissions projections. Generally, GDP exhibits a positive effect on GHG emission projections in the observed data for the year 2021. This indicates that, in the reported data for the reference year 2021, the GHG emissions projections for most MS increase with an increase in GDP, with the exceptions of PL and ES.

For the period 2021-2030, during which more PaMs are anticipated to be implemented or existing PaMs intensified compared to the reference observed data (2021), GDP has a consistent positive effect for about half of the MS. Specifically, five MS (Czech Republic, Bulgaria, Croatia, Estonia, Austria) show a larger effect on a 1% GDP increase, compared to 2021. Germany is the only MS where GHG emissions projections for the period show a decrease in the impact of GDP, although it remains positive. In contrast, five MS (Sweden, Latvia, Netherlands, Greece and Portugal) show that GDP has a non-positive and even a diminishing effect on GHG emissions, meaning that a 1% GDP increase results in diminished GHG emissions (%). This is presumed to be due to additional PaMs or higher intensity PaMs. Differently, Poland exhibits negative GHG emissions projections on a 1% increase in GDP for both the reference year 2021 and a slightly smaller but still negative effect in the projected period 2021-2030. Conversely, Spain shifted from a negative GHG emissions effect on GDP increase to a positive effect.

In the year 2030-2040, all elasticities are negative, suggesting that a 1% GDP increase has a diminishing effect on GHG emissions projections in percentage terms. Potential explanations include miscalculations in the reported parameters affecting the reported GHG emissions projections, MS overestimating the impact of future PaMs, MS tending to overestimate GHG emissions in future periods, or the utilisation of different parameters not considered in the current modelling.

In the period 2040-2050, elasticities tend to zero, reflecting the lack of MS reporting for this timeframe in their projections. As a result, these elasticities are not very informative or relevant.

Sweden and Latvia exemplify MS displaying a decreasing trend in GHG emissions projections with respect to economic growth. In Sweden, a 1% increase in GDP for the year 2021 results in a 0.04% increase in GHG emissions. Over the period 2021-2030, projections indicate that GHG emissions decrease by 0.18% for every 1% increase in economic growth, further declining by 2.17% in the period 2030-2040. Similarly, Latvia exhibits a diminishing emission trend in response to GDP growth. These trends suggest that PaMs in these countries are becoming more stringent and efficient without compromising economic growth.

Notably, significant observed elasticities, such as those in the case of the Czech Republic in 2021 and 2021-2030, indicate that GDP has a substantial impact on GHG emissions for the respective years in those particular MS. However, in the period 2030-2040, there is a significant drop in elasticity, which may seem unusual. This trend is expected in countries where GDP is strongly linked to emissions, particularly those with an industry-intensive GDP, such as Italy, Germany, France, and Czechia.

Trend transitions, exemplified by Spain, necessitate thoughtful interpretation. The pattern shifts from a negative correlation in 2021, indicating that economic growth initially led to reduced GHG emissions (one-unit GDP growth resulted in fewer emissions), to a positive correlation in the period 2021-2030, suggesting a reversal where economic growth increased emissions. Subsequently, in the period 2030-2040, the trend shifts back to a negative correlation, indicating a return to a scenario where economic growth is associated with reduced GHG emissions.

Caution is advised when interpreting negative elasticities, as they statistically suggest a diminishing effect of GDP on GHG emissions. While this aligns with the positive goal of reducing GHG emissions, it may also indicate issues with the proxy used (e.g., reported GDP by the MS) or concerns with the employed modelling approach. Alterations in elasticity signs or an amplification of proxy influence, particularly when PaMs are expected to decrease impact, may signal potential issues with proxies or the modelling approach.

Evidence suggests the need for further in-depth analysis, as these conclusions require a more nuanced examination to ensure accuracy. The tables illustrating the temporal evolution for all analysed IPCC categories can be found in Annex 1 of this document.

Further analysis of the temporal evolution of GHG emissions, considering their relationship with predictor variables, is undertaken. The process begins by ensuring the completeness of the dataset, involving the preparation of a dataset containing projections and associated proxies for the specific category. To address gaps in proxy data, linear interpolation is employed. Subsequently, the dataset is divided into temporal segments for analysis, creating various partitions ranging from one part to the maximum possible, ensuring a minimum of three years in each partition (Diagram 1).

Within each partition, the correlation between emission projections and each predictor variable is evaluated, and the predictor variable (proxy) with the lowest correlation p-value is selected. A low p-value (< 0.05) in hypothesis testing indicates that the coefficient is likely not zero, suggesting statistical significance and affirming the influence of the explanatory variable on the dependent variable.

Despite variations in length across different temporal partitions, equitable weighting of variables is applied to ensure a fair representation. To gain insights into the temporal impact of proxies by sector, a visual representation is provided, illustrating the explanatory power of predictor variables on GHG emissions within specific time periods for each sector or category. Colours are assigned to different predictor variables, with light or dark shades reflecting the variable's weighting in each temporal segment. The colouring becomes more prominent when the variable has more weight in that temporal segment, meaning that sometimes the colour is clear, and sometimes there are only tones of the colour that, in combination with the other colours in the plot, will display different tints and shades.

Diagram 1. Illustrative representation of the proxy partition.

<table>
<tr><td colspan="8">Proxy 1</td></tr>
<tr><td colspan="4">Proxy 1</td><td colspan="4">Proxy 2</td></tr>
<tr><td colspan="2">Proxy 1</td><td colspan="2">Proxy 2</td><td colspan="2">Proxy 2</td><td colspan="2">Proxy 1</td></tr>
<tr><td>Proxy 1</td><td>Proxy 2</td><td>Proxy 2</td><td>Proxy 1</td><td>Proxy 2</td><td>Proxy 1</td><td>Proxy 1</td><td>Proxy 1</td></tr>
</table>

Figures 4 and 5 depict the emissions evolution by proxies for categories 1.A.1 and 1.A.2, chosen for having more than one valid variable after addressing autocorrelations and linearity. This approach is extendable to all categories if sufficient proxies are available to avoid reliance on a single proxy. In both cases, GDP (red) and EU ETS Carbon Price (green) serve as proxies. As mentioned before, each variable has a specific colour assigned; however, the intensity or clarity of the colour will be better noticed when the weight of the variable in each temporal segment predominates over the other. In the following plots, EU ETS carbon price prevails over the different time spans of each specific plot, yet the tones and tints change as GDP-Constant prices take more variable weighting in each temporal segment.

Figure 4 Emission evolution by proxies: 1.A.1. Czechia (left) 1.A.2. Romania (right)

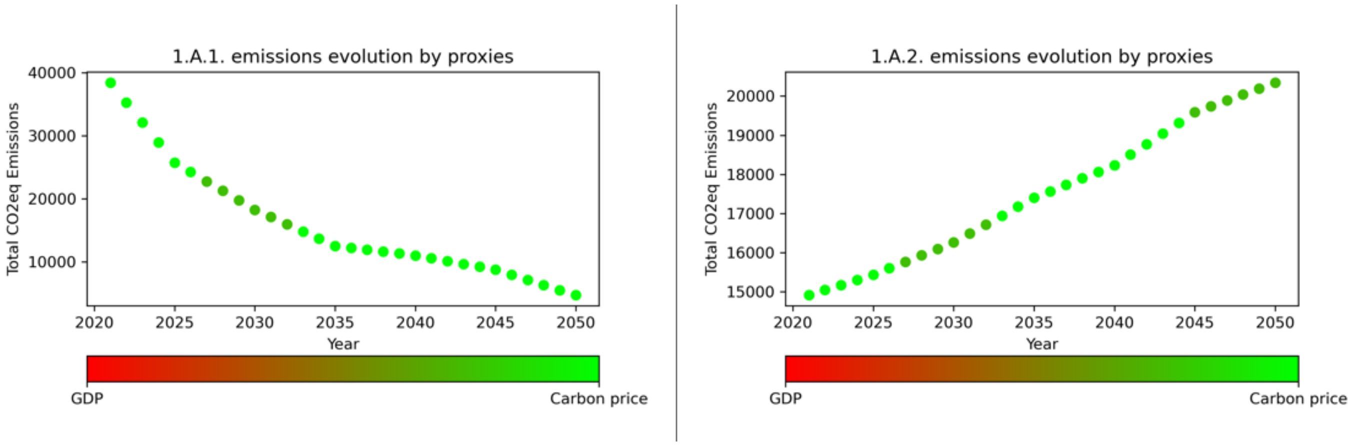
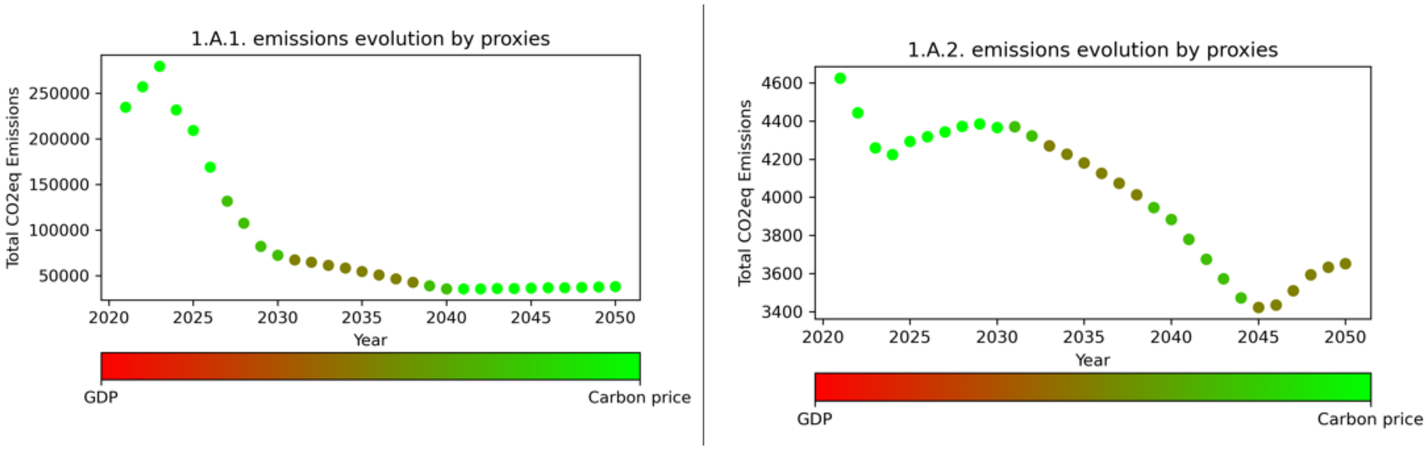


Figure 5 Emission evolution by proxies: 1.A.1. Germany (left) 1.A.2. Ireland (right)



The analysis underscores the significant influence of coal prices on more consistent temporal evolutions, particularly evident in the cases of Czechia and Romania, representing categories 1.A.1. and 1.A.2., respectively. Notably, from 2026 to 2033 in Czechia and 2027 to 2032 in Romania, the proxy GDP demonstrates limited power as a driver for GHG emissions.

Conversely, examining the same categories for Germany and Ireland, GDP-Constant prices emerge as slightly more impactful proxies in shaping emissions evolution. Specifically, this effect is notable in the period between 2030-2040 for Germany and during two intervals for Ireland—from approximately 2033 to 2037 and from 2045 to 2050. It is observed that abrupt variations in GHG emissions coincide with an increase in the influence of GDP on emissions. However, it is crucial to note that this observation pertains to fluctuations in the general trend rather than indicating a specific increase or decrease in GHG emissions.

A potential explanation lies in the economic system's impact on GHG emissions, particularly the influence of the carbon price on changing trends. Changes are not directly from price fluctuations but result from shifts in the coal price market. In a stable system where supply and demand determine prices, alterations in demand for an industry element led to price fluctuations, impacting the production of that element, and subsequently affecting GHG emissions. Essentially, the system's equilibrium is disrupted, changing element prices, production, and supply in response to shifts in demand. Similar effects would occur with changes in the supply side.

4.2 Part 2. Assessment of the consistency between reported PaMs and emission projections

4.2.1 Step 1 & 2: Model Results

The comprehensive outcomes of the regression analysis for each sector can be found in Annex 2.1. Each sectoral table details country-specific results, including coefficients, constant terms, and the statistical significance of each coefficient. The tables also feature regression statistical results in terms of the coefficient of determination (R^2) and the p-value of the F-test (significance F).

Additionally, Annex 2.1 tables include a check to ascertain whether the regression analysis for each country is based on a minimum of five sectoral PaMs over at least a five-year period. Coefficients for *PAMst* and/or *PAMlt* in countries failing this criterion are flagged, indicating positive relationships with GHG emissions, outliers, or low statistical significance. Equations not meeting this criterion are excluded from estimating future projections.

Table 11 provides a statistical summary of regression results, showcasing average, minimum, and maximum values for coefficients and constant terms per sector, considering results from each country. Equal weighting is applied to countries, irrespective of size or GHG emissions levels. Thus, Table 11 offers indicative overall trends rather than an average for the EU region. The statistical summary is based on countries meeting the criterion of at least five PaMs per sector over a five-year period and results with a negative coefficient for *PAMst* or *PAMlt*. The number of country observations considered for summary results is also indicated in the same table. Refer to tables in Annex 2 for a detailed breakdown of results by country and sector.

Fuel combustion activities (sectors 1.A.1, 1.A.2, 1.A.3, and 1.A.4) have the highest number of countries with relevant regression results, aligning with the significant share of PaMs targeting these sectors. Conversely, PaMs targeting industrial processes, agriculture, LULUCF and waste sectors are less pronounced across all countries. In cases where implemented, the number of PaMs generally falls below the threshold for considering regression results relevant.

It is crucial to note that GHG emissions and GDP per capita are measured in their natural logarithm in the equations. Therefore, results for the coefficients should be interpreted in terms of percentage changes.

Table 10 **Statistical summary of the countries regression coefficient results, by GHG sector.**

	$PAMst$	$PAMlt$	$lnGDPpc$	Constant
1.A.1 Energy Industries				
Average	-0.018	-0.035	0.603	4.205
Minimum	-0.002	-0.002	-0.665	-9.368
Maximum	-0.037	-0.082	2.072	15.481
Number of observed countries	17	22	22	22
1.A.2 Manufacturing Industries and Construction				
Average coefficient	-0.029	-0.036	0.450	4.694
Minimum	-0.002	-0.003	-1.099	-20.951
Maximum	-0.110	-0.133	3.143	20.251
Number of observed countries	16	20	20	20
1.A.3 Transport				
Average coefficient	-0.011	-0.024	0.959	-0.118
Minimum	-0.001	-0.003	0.372	-9.775
Maximum	-0.024	-0.054	1.713	5.834
Number of observed countries	12	17	17	17
1.A.4 Other Sectors (Commercial/Institutional, Residential, Agriculture/Forestry/Fishing)				
Average coefficient	-0.020	-0.028	-0.190	11.418
Minimum	-0.001	0.000	-3.442	-2.416
Maximum	-0.066	-0.143	1.147	45.179
Number of observed countries	14	20	20	20
2. Industrial Processes and Product Use				
Average coefficient	-0.028	-0.054	0.576	3.937
Minimum	-0.011	-0.023	-0.331	-5.154
Maximum	-0.058	-0.099	1.447	14.407
Number of observed countries	5	5	5	5
3. Agriculture				
Average coefficient	-0.005	-0.005	-0.155	11.782
Minimum	-0.004	0.000	-0.406	9.777
Maximum	-0.006	-0.011	-0.027	15.432
Number of observed countries	2	3	3	3
4. Land Use, Land-Use Change and Forestry				
No relevant/significant results				
5. Waste				
Average coefficient	-0.052	-0.054	-0.272	11.435
Minimum	-0.024	-0.007	-0.657	8.182
Maximum	-0.105	-0.193	0.067	15.507
Number of observed countries	3	5	5	5

Note: These statistical results are based on relevant country results only, taking account of counties which have a minimum of five sectoral PaMs implemented over a period of at least five years. Coefficients for $PAMst$ or $PAMlt$ which have a positive sign are also omitted. Annex 2 provides full regression results per country and per sector.

Based on overall results, on average a new climate and energy policy or measure reduces GHG emissions in fuel combustion sectors by 1.1% to 2.9% in the short term, depending on the sub-sector. Accumulating another policy or measure in the longer-term results in emission reduction between 2.4% and 3.6%, depending on the sub-sector.

The effectiveness of PaMs to reduce GHG emissions is most notable in the industrial processes sector, where a new policy or measure, on average is estimated to cut emissions by 2.8% and 5.4% in the short-and long-term, respectively. PaMs targeting the waste sector also have a noticeable effect on average of 5.2% and 5.4% in the short- and long-term, respectively. Conversely, the effectiveness of PaMs targeting agricultural emissions is the lowest at an average of 0.5% in both the short- and long-term. Note that results for the latter three sectors are based on five countries or fewer and are not representative of the EU-27 countries. All results for the LULUCF sector are not considered relevant, therefore they are not presented here.

These results align with expectations that older PaMs have a stronger effect on reducing GHG emissions than more recent ones. The results are comparable to the findings of Eskander & Fankhauser's study (2020), which are based on data for 133 countries worldwide, suggesting that passing a climate change law has a negative effect on CO_2 emissions of 0.78% and 1.79% in the short- and long-term, respectively.

As mentioned earlier, the effects of PaMs are estimated for all sectoral PaMs contributing to the three key dimensions (GHG removals, renewable energy, and energy efficiency). The model is also tested with variables for *PAMst* and *PAMlt* for each dimension separately to assess whether the effectiveness of policy varies by dimension. However, the statistical significance of results worsens when using separate dimension variables, likely due to a lack of quality in reporting by countries, where PaMs are sometimes indicated to contribute to both renewable energy and energy efficiency dimensions erroneously. Due to this, the effects of PaMs are aggregated for different dimensions under *PAMst* and *PAMlt.*

Results for the elasticity of emissions to GDP per capita indicate that, generally, sectoral emissions grow with GDP per capita but at a relatively slower rate, suggesting a level of relative decoupling. This trend, however, is not observed across the entire region, as some countries have a GDP per capita elasticity higher than 1, indicating no decoupling. For fuel combustion sectors, on average, a 1% change in GDP per capita results in an average increase of 0.45%, 0.60%, and 0.96% in the emissions of the manufacturing, energy, and transport sectors, respectively. The GDP per capita elasticity for '1.A.4 Other sectors', on average, is negative at 0.19, indicating possible absolute decoupling of the sector in most countries. For industrial processes, the GDP per capita elasticity is estimated at an average of 0.58, whilst for agriculture and waste sectors this is estimated to be negative at 0.16 and 0.27, respectively; however, these results are not representative of the entire region as they are based on the results of five countries or fewer.

Where regression results are accepted, sectoral GHG emission projections up to 2030 are estimated using country model results. The projected values per country are depicted in charts per sector in Annex 2 for WEM and WAM scenarios, respectively, where reported projections are compared to estimated projections. As with any projection work based on historical data, this approach has limitations, assuming that historical information remains relevant for the future period. It assumes that the governance system, rule of law within a country, and any other underlying drivers of emissions would on average remain the same as in the past. It also assumes that planned PaMs on average will have a similar effectiveness as PaMs implemented in the past.

4.2.2 Step 3: Assessment of consistency between GHG emission projections and reported PaMs

A number of countries are selected to illustrate the application of consistency checks and showcase potential findings that can be obtained through these checks.

Assessing the consistency of WEM and WAM scenario projections with reported PaMs

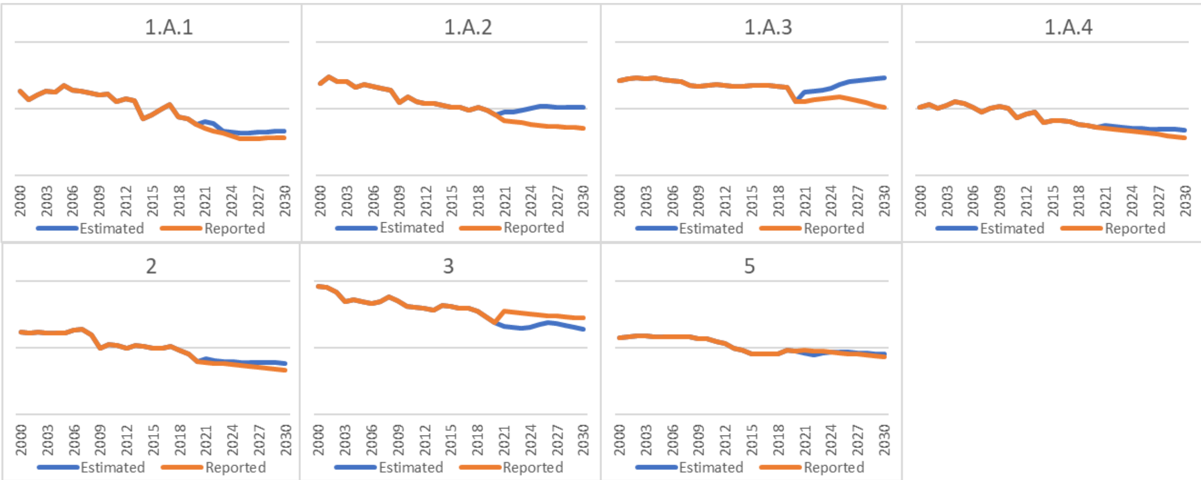
The projections that are estimated using the results of the regression analysis can serve as a tool to assess whether WEM and WAM projections reported by MS are consistent with the expected emissions trajectories when accounting for the effects of PaMs. Annex 2 provide charts per country and sector, facilitating a comparison between reported and estimated projections up to 2030 for WEM and WAM scenarios, respectively. These charts provide the basis to assess whether the annual levels and the overall trend direction of reported projections are comparable to the estimated projections.

Generally, sectoral projections align reasonably well with historical emission trends. On a country level, reported projections closely match estimated projections for some countries in terms of magnitude and direction. Where deviations occur, they can be positive or negative, suggesting that the model outcomes do not systematically over or under-estimate emission levels.

Two countries, France and Romania, are selected for illustrative consistency checks. Figure 6 and Figure 7 demonstrate the comparative charts of the WEM scenario for France and WAM scenario for Romania.

The WEM scenario charts for **France** show overall realistic projections across sectors, aligning closely with expected trajectories. A detailed sectoral analysis reveals that sector 1.A.1 Energy Industries, 1.A.4 Other Sectors, 2. IPPU, and 5. Waste demonstrate minimal deviations between reported and estimated emission paths. This similarity in evolution indicates that the 17 implemented PaMs targeting energy supply and consumption are well-captured in the long-term effects on GHG emissions. Similarly, the impact of seven PaMs in the industrial sector and six in the waste sector is effectively reflected in both reported and estimated projections, ensuring a relatively comparable trajectory.

Figure 6 Comparison of reported and estimated WEM emissions projections for France, by sector.



In contrast, the manufacturing (1.A.2) and transport (1.A.3) sectors exhibit upward deviations in estimated trajectories compared to reported projections. This divergence stems from the stronger impact of recently implemented PaMs compared to older ones, as indicated by regression results. Analysing the cause of this upward trend, Table 4.12 outlines the annual effects of changes in the number of PaMs and GDP per capita on sector 1.A.2 emissions. Anticipated gradual reductions in the number of recently implemented PaMs between 2020 and 2024 contribute to an emissions increase, driven by the negative coefficient of *PAMst*. While older PaMs retain some long-term effects, the weaker coefficient for *PAMlt* means their emission reductions are insufficient to counterbalance the rise linked to the declining number of newer PaMs. Although PaMs implementation effectively reduces net emissions compared to a baseline scenario, the interplay between positive and negative effects leads to a net increase in sectoral emissions over time. Nevertheless, without these PaMs, emissions for the sector would be expected to be higher.

Table 11 **Annual estimation of the effects of each variable on GHG emissions for sector 1.A.2 Manufacturing Industries and Construction sector for France, in the WEM scenario.**

Year	Number of recently implemented PaMs	Cumulative number of older PaMs	Effect on emissions from changes in number of recent PaMs	Effect on emissions from changes in number of older PaMs	Effect on emissions from changes in GDP per capita	Annual emissions level
Unit	*Count*	*count*	*kt CO_2-eq*	*kt CO_2-eq*	*kt CO_2-eq*	*kt CO_2-eq*
2020	9	27				45,492.52
2021	8	31	919.47	- 1,270.7	- 290.97	47,444.32
2022	7	34	906.97	- 940.1	- 133.19	47,278.02
2023	5	36	1,807.47	- 624.5	- 24.39	48,436.62
2024	2	39	2,778.84	- 960.1	- 59.69	50,195.68
2025	-	41	1,921.03	- 663.7	- 67.05	51,385.94
2026	-	41	-	-	- 75.05	51,310.89
2027	-	41	-	-	- 80.21	51,230.68
2028	-	41	-	-	- 85.34	51,145.34
2029	-	41	-	-	- 90.45	51,054.88
2030	-	41	-	-	- 95.53	50,959.35

Short-Term vs. Long-Term Impact of PaMs: The observed stronger short-term effects of PaMs in certain sectors suggest a historical reliance on policies with relatively brief effectiveness. This pattern may be attributed to policy instruments; for instance, educational and informational approaches tend to yield shorter-term results compared to economic or regulatory instruments, which manifest more significantly over the long term. Consequently, when interpreting projection outcomes, it becomes imperative to scrutinise the basis for higher coefficients associated with short-term PaMs (*PAMst*) in contrast to long-term PaMs (P*AMlt*).

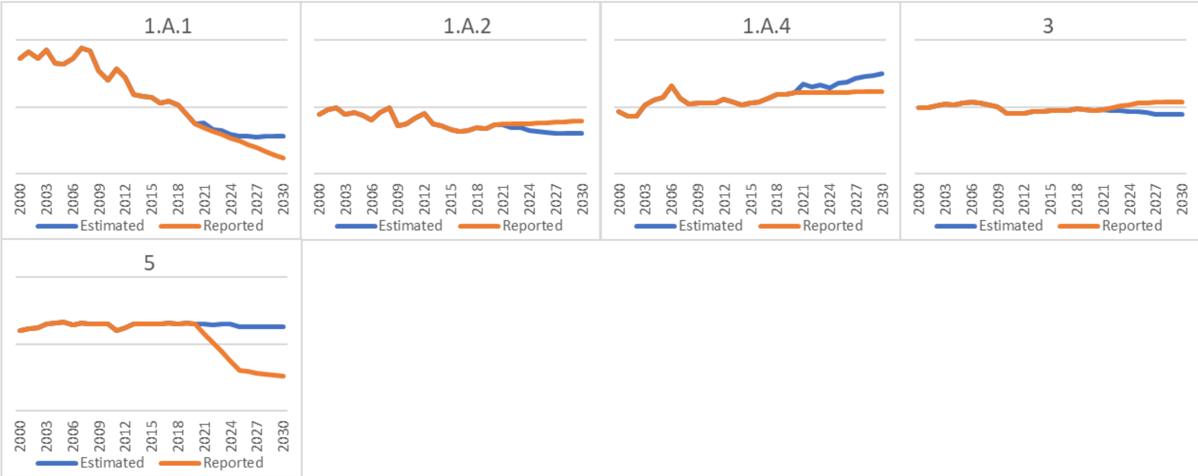
Similar dynamics are noted in the agricultural sector (3), where short-term PaMs exhibit relatively more impact than their long-term counterparts. While reported projections differ in timing compared to estimated trajectories, the overall trend remains relatively consistent.

In **Romania**, reported trends align overall with realistic expectations. However, a noteworthy anomaly emerges in the waste sector (5), where the reporting country projects a substantial emission reduction by 2025, reaching less than half of the 2020 level. Seven new PaMs targeting waste management are reported between 2001 and 2023, yet the estimated trajectory indicates a relatively flat trend. Despite 10 PaMs being implemented in recent years, their efficacy in reducing GHG emissions is notably low, reflected in a marginal long-term coefficient of -0.007. This stark disparity prompts questions about the feasibility of the reported emission reduction, urging verification against integrated climate and energy PaMs reporting or other technical reports.

For the energy industry sector (1.A.1) and residential/commercial sectors (1.A.4), reported trends fall below estimated trajectories, especially in the latter half of the projected period. This discrepancy may suggest an anticipation of stronger long-term impacts by reporters from planned PaMs. The notably linear trend extending to 2030 raises inquiries into whether projections adequately account for the effects of implemented or planned PaMs.

Conservatism in Reported Trends: Conversely, in the manufacturing (1.A.2) and agricultural (3) sectors, reported trends lean towards conservatism compared to estimated trajectories. While reported trends indicate a slight increase in emissions, estimated projections portray a relatively flatter but slightly descending path. This conservative stance by reporters prompts questions about the inclusion of sectoral PaMs implemented after 2020 in the projection estimates.

Figure 7 Comparison of reported and estimated WAM emissions projections for Romania, by sector.



Assessing the consistency of difference between WAM and WEM scenario projections with planned PaMs

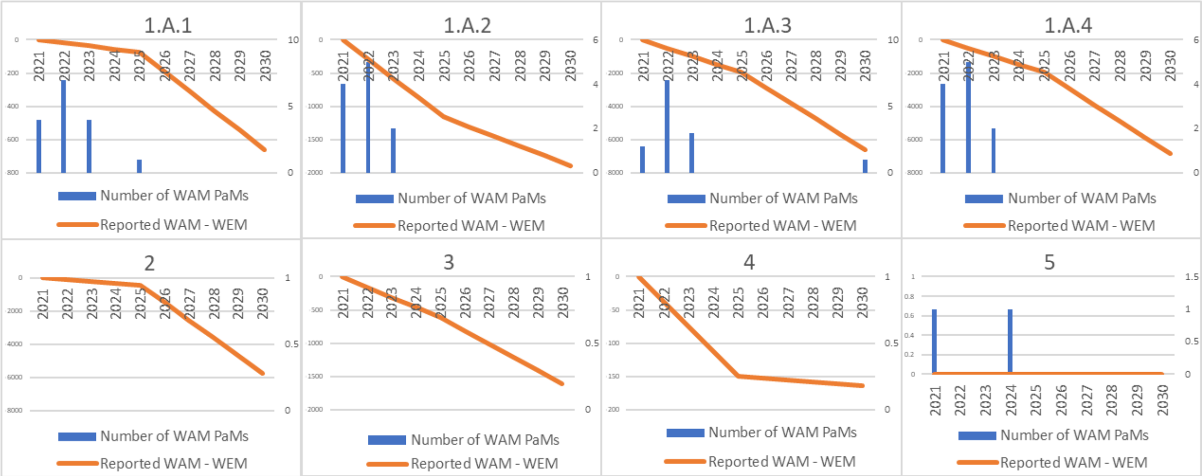
To assess consistency, the reported emissions disparities between WAM and WEM scenarios are scrutinised in relation to the reported planned PaMs. A discrepancy between WAM and WEM scenarios typically implies the presence of planned PaMs, particularly if the difference is substantial. Conversely, equal WAM and WEM scenarios suggest either the absence of reported planned PaMs in WAM or, if any exist, their impact is likely marginal.

Illustrating these checks with Figures 8 and 9, disparities between WAM and WEM projections are examined alongside planned WAM PaMs for Belgium and Finland. The charts for all countries have not been included to avoid overwhelming the document. (For reference, find them in the workbooks on Teams 4_Analysis_Workings, the last sheet 'ChartsWAM-WEM').

In Belgium's fuel combustion sectors (1.A.1, 1.A.2, 1.A.3, and 1.A.4), sharp trajectory changes around 2025 are attributed to new planned PaMs. However, for industrial processes, agriculture, and LULUCF, WAM scenarios report lower values without corresponding planned PaMs, raising questions about the completeness of reported PaMs for these sectors. Notably, the waste sector (5) has two planned PaMs, but their impact is omitted in the WAM scenario, prompting inquiry into why and whether such PaMs' effects should be considered.

In conclusion, assessing the alignment of reported emissions disparities with planned PaMs provides insights into the comprehensiveness of reported scenarios and the potential influence of unaccounted PaMs on emission trajectories.

Figure 8 **Difference between reported WAM and WEM emissions versus number of new WAM PaMs for Belgium, by sector.**

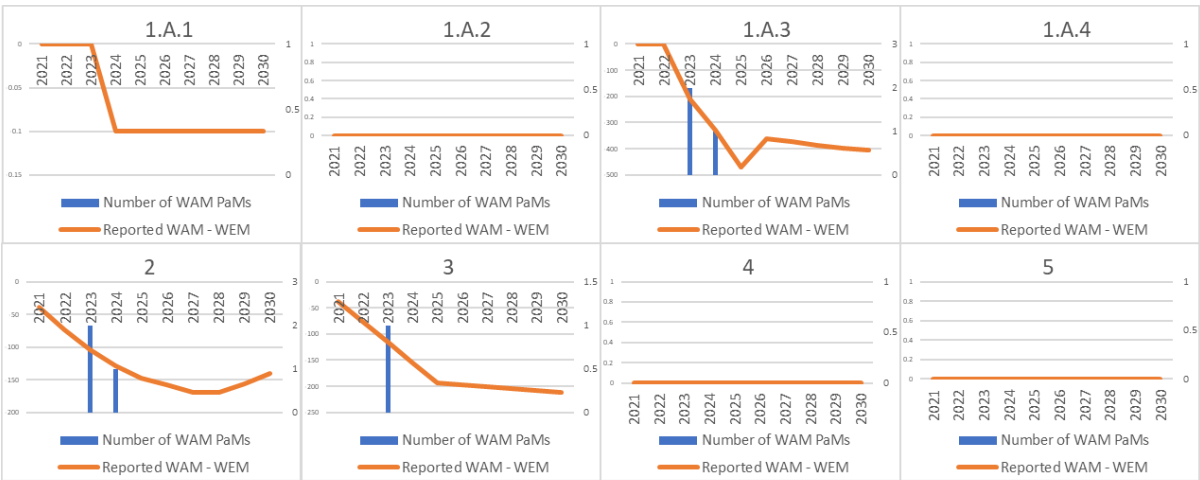


Note: The reported difference between WAM and WEM emissions in kt CO2-eq is plotted on the primary y-axis and the number of planned PaMs in the WAM scenario are plotted on the secondary y-axis.

For four sectors in **Finland** (1.A.2, 1.A.4, 4, and 5), no disparities between WAM and WEM scenarios are reported, and no new PaMs are planned in the WAM scenario, demonstrating consistency. In the transport (1.A.3), industrial processes (2), and agriculture (3) sectors, reported PaMs explain the differences between WAM and WEM emissions effectively. Each of these sectors has one or two new planned PaMs to be implemented before 2025, with disparities of around 500 kt CO2-eq or less, indicating alignment between reported PaMs and sector projections.

Contrastingly, in the energy industry sector (1.A.1), a level shift in WAM scenario projections is reported without corresponding new PaMs, prompting inquiries into the completeness of reported PaMs for the energy sector. This discrepancy suggests a potential gap in reported PaMs, questioning whether all relevant measures have been considered. Analysing these findings sheds light on the reliability of reported scenarios and the need for a comprehensive assessment of planned PaMs.

Figure 9 **Difference between reported WAM and WEM emissions versus number of new WAM PaMs for Finland, by sector.**



Note: The reported difference between WAM and WEM emissions in kt CO2-eq is plotted on the primary y-axis and the number of planned PaMs in the WAM scenario are plotted on the secondary y-axis.

4.3 Part 3. Qualitative assessment of proxies

4.3.1 Review of projection report

This analysis examines the projection reports submitted by the MS in 2023 under The Governance Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action. The reports were extracted from Reportnet 3 on October 3rd, 2023. The analysis focused on reports that were in English and disregarded non-English submissions. In addition, summary versions lacking comprehensive methodological details were also excluded.

Following the guidelines from the ETC CM working group, the MS predominantly employed a standardised format for their reports. However, content variations arose due to differences in length, comprehensiveness, terminology, and consistency. To navigate these disparities efficiently, a keyword-based approach was adopted, targeting specific areas related to projection methodologies. The used keywords were as follows:

parameter, factor*, drive*, method*, projection*, model*, activity**

** relevant combinations of words were utilised for each term in the context of the analysis.*

Table 31 (Annex 3.1) provides a detailed overview of the reviewed projection reports. Findings revealed a preference for using models to predict future activity levels, with models categorised as either generic or sector specific. Generic models adhered to IPCC guidelines, while sector-specific models varied in complexity, ranging from spreadsheet-based extrapolation to sophisticated models capturing long-term interactions and identifying elasticity, shocks, and optimality.

Sophisticated models were primarily employed in the energy sector, utilising frameworks such as TIMES, MESSAGE, and econometric input-output data. Limited instances of advanced modelling outside the energy sector were noted; for example, Austria utilised the PASMA model for agricultural projections, integrating outcomes with ADAGIO and WIFO's input-output model to assess economic impacts.

Despite detailing the basis of projections in each sector, the methodology sections often lacked information on activity drivers (input parameters). Locating such information proved challenging, as activity drivers were sporadically mentioned without source attribution. Understanding the significance and correlations of these drivers across sectors was particularly elusive.

Additionally, National Energy and Climate Plans (NECP)—draft updated 2021-2023—were reviewed with similar challenges encountered. Consequently, a decision was made to assess submitted activity drivers in a tabular format on Reportnet (i.e., Table 3: Reporting on parameters / variables for projections of GovReg). This subsequent analysis aims to identify reported activity drivers, their nature, any commonalities between the MS, and the origins of these drivers.

4.3.2 Review of the submitted activity drivers on Reportnet 3

Reviewing the submitted activity drivers to “Table 3: Reporting on parameters / variables for projections” is carried out to find out the activity drivers (it is referred to the parameters and variables in Table 3 of GovReg) used for the projections. Table 3 of GovReg only reports activity drivers that are used as input/output to the modelling of projections.

Table 13 (Annex 1.1) illustrates a striking diversity in the reported parameters across MS, as evident in Figure 10[4]. Approximately 62% of reported activity drivers contribute to GHG projections, with notable variations in the counts across the MS. For instance, Slovenia lists over 90 activity drivers, while Malta and Cyprus report fewer than 20 each.

Figure 10 Activity drivers covered by the Member States.

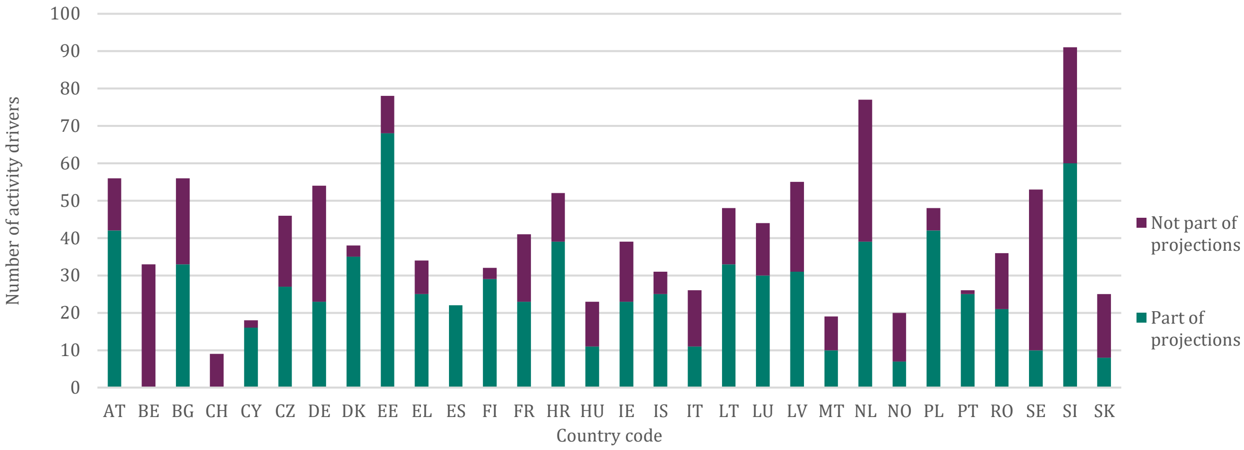
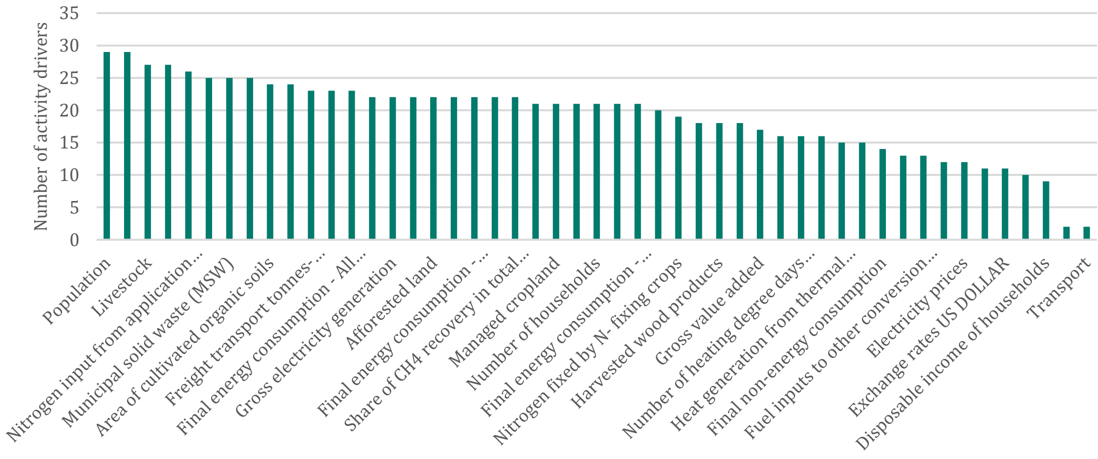


Figure 11[5] delves into the frequency of reporting similar activity drivers, revealing that of the 190 reported, only 49 are common among at least two MS. Population and gross domestic product feature prominently, with widespread coverage except in Cyprus and Belgium. Conversely, industry and transport are exclusive to the Netherlands and Slovenia. It is crucial to scrutinise these findings, as discrepancies might arise from Reportnet's data fetching tool.

Figure 11 Frequency of similar activity drivers mentioned by the MS in Table 3: Reporting on parameters / variables for projections of GovReg.

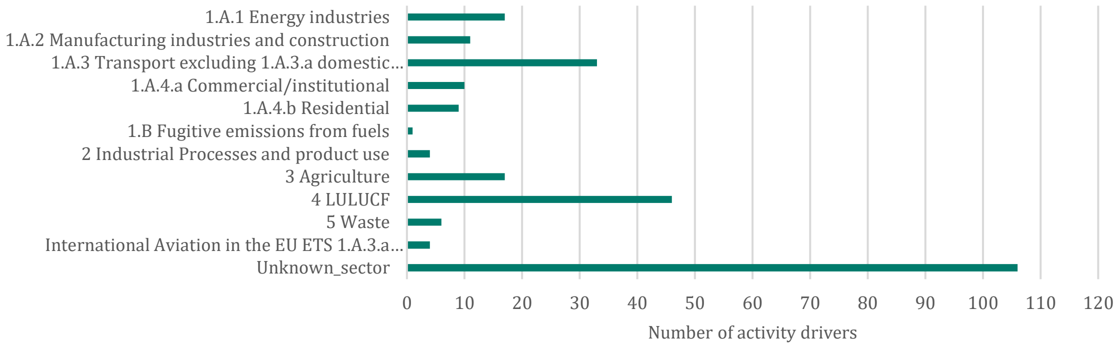


4 Figure 10 is derived from Table 32 (Annex 3.2).

5 Figure 3 is derived from Table 33 (Annex 3.3).

While Figure 11 provides insight into the relevance of activity drivers for GHG projections, Figure 12[6] connects these drivers to the IPCC's sectors[7]. LULUCF emerges as the most reported sector, utilising over 45 activity drivers, including land use conversions. In contrast, more than 100 activity drivers lack correspondence to any IPCC sector, warranting further investigation.

Figure 12 Number of activity drivers corresponding to IPCC categories, as well as activity drivers with no connection to any sector.



Discrepancies arise when comparing the total number of reported activity drivers (Figure 11) with those for IPCC categories (Figure 12) due to multiple uses of certain drivers across sectors. For instance, population serves both the '1.A.4.b Residential' and '5 Waste' sectors. Identifying and assessing the significance of such shared activity drivers remains challenging, compounded by the difficulty of discerning their importance in methodology reports.

It is essential to acknowledge that the presented figures (Figure 10, 11 and 12) offer a glimpse into the coverage and diversity of activity drivers but may not capture sub-activity drivers. Future work could explore these nuances to gain a more comprehensive understanding.

A primary objective of reviewing activity drivers was to identify their data sources. Unfortunately, the tabular data from Reportnet 3 lacks information on sources and assumptions. Some MS, like the Netherlands, provided valuable insights through annexes accompanying their NECP draft reports. However, challenges arose from variations in spelling and formatting, necessitating enhanced data quality control and assurance measures.

This analysis sheds light on the intricate landscape of reported activity drivers, emphasising the need for precision in reporting and exploring deeper levels of sub-activity drivers for a more nuanced understanding.

4.3.3 Experts' inputs

To enhance our understanding of the selection and ranking of activity drivers in GHG projections, insights were sought from experts identified through the Reportnet contact list. Specifically, the posed questions

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6 Figure 12 is derived from Table 34 (Annex A.3.2.). In this table, one can also find activity drivers that are used for the projection of certain IPCC sectors. For more information on the presented figure, please look at the appended table.

7 This study refers to IPCC sectors and categories. However, the nomenclature is the one reported by Member States, i.e. the Common Reporting Format.

were related to the connection between reported activity drivers (as per Table 3: Reporting on parameters / variables for projections in Governance Regulation [8]) and their corresponding to the IPCC's sectors/categories. The aim was to clarify discrepancies where certain activity drivers lacked clear links to designated sectors. Experts were also asked to specify whether there exist activity drivers that were now excluded but that could potentially have a big impact on the GHG projection outcomes. The latter question was raised to gain insight into best practices and to tap into new activity drivers and data sources.

10 European countries—Austria, Belgium, Denmark, France, Ireland, Germany, the Netherlands, Norway, Portugal, and Spain—received our inquiries. While responses have been received only from the Netherlands and Spain at this point, their insights are valuable.

In addressing our first question, the Netherlands highlighted a provided spreadsheet corresponding to "Table 3: Reporting on parameters / variables for projections" in Governance Regulation, submitted with their NECP. While the spreadsheet contained additional information, such as assumptions and data sources not available in the extracted table from Reportnet, it did not fully address our query on the linkage between specific activity drivers and the IPCC's sectors.

Spain provided detail explanation on the used model in their GHG projections and used activity drivers. The TIMES-SINERGIA energy forecasting model incorporates macroeconomic drivers, including GDP and population, as well as fuel prices. The energy model was used in (1) energy (excluding transport), (2) transport, and (3) industrial processes and product use. In the remaining sectors, the used drivers had an indigenous nature and PaMs implementation. For example, the following drivers were used in the agricultural sector: number of animals of each type and fertilizer use projected by the Ministry of these projected data, as well as forecasts for BAT and PaMs implementation.

Concerning our second question on potential excluded activity drivers with significant impacts on GHG projections, the Netherlands, unfortunately, could not provide a response as their work relied on results from other experts. Closely, Spain could not provide answer to our second question.

This initial expert consultation emphasises the need for clearer documentation of the relationship between activity drivers and IPCC sectors in GHG projections. The absence of responses from other countries underscores the importance of continued collaboration and knowledge-sharing within the expert community to improve practices and identify valuable data sources for robust GHG projections.

4.3.4 Discussion

The relationship between population growth, affluence-driven consumption, and environmental stress is well-established. However, understanding the comprehensive drivers of environmental change requires a broader perspective. Beyond population and affluence, technology, institutional structures, and culture play pivotal roles in shaping behaviours and influencing anthropogenic climate change. The complex interplay among these drivers necessitates a nuanced analysis.

Early groundwork by Ehrlich and Holdren (Ehrlich & Holdren, 1971) delineated three time-dependent drivers—population, affluence (income per capita), and technology—as the primary contributors to human impact on the environment. This conceptual framework inspired subsequent decomposition analyses, with Yoichi Kaya (Kaya, 1990) expanding it further. Kaya's model introduced distinctions in technology drivers, considering overall energy intensity of GDP and carbon intensity of energy to gain deeper insights into energy consumption and CO_2 emissions. However, these models, such as IPAT/Kaya,

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[8] Table 3 - Reporting on parameters / variables for projections, within the reporting on GHG projections under Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action.

are more suitable for retrospective analyses, explaining the contribution of predefined drivers to environmental stress.

In contrast, GHG projection models like MESSAGE, NEMA, and AGM adopt a prospective approach. These models integrate policy, technology, and economic modules to project GHG emissions and track progress towards targets. While the activity drivers in these modules vary among models, their comprehensive nature raises questions about their ability to capture dynamics like ethics and shocks.

Climate change’s global nature transcends economic and environmental challenges, introducing ethical considerations. Distributive justice becomes paramount, as developing nations, despite contributing less to the problem, bear a disproportionate burden. Addressing ethical issues is imperative in ensuring a fair global distribution of responsibilities, especially considering the far-reaching and intergenerational impacts of climate change.

The enduring consequences of climate change underscore the need for ethical decision-making. Decisions made today affect future generations, emphasising the importance of a lifecycle perspective. Despite challenges in fully assessing the consequences of various actions, prioritising the well-being and rights of future generations is essential to avoid repeating past mistakes and make informed decisions with minimal negative consequences.

Moreover, shocks, defined as sudden and disruptive events like the 2008 financial crisis, the Ukraine war, and the Covid-19 pandemic, can reshape systems and alter emission patterns. The reconfiguration of supply chains in response to these events influences domestic emission accounts, highlighting the interconnectedness of global shocks and emissions dynamics. It is of relevance to investigate the system resilience and response to such changes.

5 Conclusions and Recommendations

This study aimed to enhance the QA/QC of GHG emissions projections, providing insights into the drivers influencing projections for more accurate reporting by MS. The **quantitative empirical analysis assessed GHG emissions trends and the consistency between PaMs and emissions scenarios**, yielding relevant results. Complementarily, a **qualitative analysis** built on the foundation of parameters or proxies, was conducted. Proxies or parameters, serving as indirect measures of the desired outcome and forming part of the ETC recommended list, were employed to study GHG emission drivers, analysing different emission trajectories across time and MS. While a standardised methodology was developed, it became evident that a uniform proxy selection approach may not be universally effective due to variations in economic structures, emission intensities, and PaMs across MS.

The **qualitative analysis** faced granularity limitations, stemming from missing data and non-stationarity issues in selected IPCC sector categories, impacting the identification of proxies/parameters. Meanwhile, the **parameter selection** process adhered to rigorous criteria, encompassing theoretical foundation, prevalence in reporting, non-stationarity confirmation through the ADF test, and verification of multicollinearity through the VIF. The recurrent use of proxies across diverse IPCC categories underscored their informativeness. However, **empirical analysis** brought to light potential inconsistencies in proxy application, especially concerning carbon price and GDP, unveiling substantial variations in elasticity values between the EU average and individual countries and underscoring the imperative for further exploration.

An exploration of the **temporal profile of drivers** revealed noteworthy variations within specific MS over different years and across various MS for a given year. Some countries displayed a declining trend in emissions alongside economic growth, while others necessitated more in-depth analysis due to due to the contradictory trends associated with expected impacts of PaMs on reducing GHG emissions while sustaining economic growth. Changes in elasticity signs and the amplification of proxy influence hinted at potential issues with proxies or the modelling approach, emphasising the interconnected impact of the economic system on emissions trends.

The **in-depth analysis**, integrating up to four proxies and weighting them differently across segmented periods, found that two proxies sufficed for certain sectors analysis. Abrupt variations in emissions coincided with increased GDP influence, indicating the economic system's impact. It's important to note, however, that these shifts pertained to fluctuations in the overall trend rather than specific emission changes, emphasizing the complexity of the relationship between economic factors and emissions.

Based on the assessment of **consistency between policies and measures and emission projections,** the results indicate that a new climate and energy PaM can lead to short-term reductions in GHG emissions in fuel combustion sectors by an average of 1.1% to 2.9%, with additional PaMs implemented in the longer-term resulting in average reductions between 2.4% and 3.6%. Notably, the effectiveness is most pronounced in industrial processes and waste sectors, emphasising the impact of older PaMs compared to recent ones.

The elasticity of emissions to GDP per capita reveals that, generally, sectoral emissions grow with GDP per capita, albeit at a slower rate, indicating relative decoupling. However, variations exist among sectors, with some displaying possible absolute decoupling. Fuel combustion sectors, for instance, show a 1% change in GDP per capita leading to emissions increases at an average of 0.45% to 0.96%, while '1.A.4 Other sectors' exhibit negative elasticity, suggesting potential absolute decoupling.

Consistency checks between WEM and WAM scenarios, exemplified by case studies of France and Romania, expose sector-specific deviations and potential discrepancies in reported projections. The short-term versus long-term impacts of PaMs underscore a historical reliance on policies with varying effectiveness. Conservative trends in reported emissions raise questions about the inclusion of newer PaMs, while disparities between WAM and WEM scenarios suggest potential gaps in reported PaMs.

The 2023 evaluation of MS projection reports on anthropogenic GHG emissions also revealed challenges in standardisation and content variations, particularly in model-based projections, showcasing differences among MS. The focused tabular analysis of activity drivers on Reportnet 3 exposed diversity among MS in the number and frequency of driver inclusion in GHG projections. Approximately 62% of reported drivers were integrated into projections, with only 49 consistently covered by at least two MS, highlighting the need for enhanced data quality control. It was also found that population and GDP were commonly reported, while others, such as industry and transport, were unique to specific nations. A review of 21 selected scientific articles further underscored the importance of purchasing power parity (PPP)-based GDP (and GDP per capita) and resource endowment in GHG projections. This complements the former conclusions from the quantitative analysis, emphasising the argument for streamlining the list of recommended parameters by the ETC into a more consolidated version that genuinely contributes to insightful GHG emissions projections. Such streamlining aims to avoid a lengthy and overly specific list that may lead to information ambiguity and lacks informativeness among MS data.

The evident need for more data and improved data quality is a key takeaway from the analysis. This necessity is underscored by the presented evidence, emphasising the importance of a nuanced examination for accurate conclusions. Future analyses integrated into the ETC QA/QC process should provide refined recommendations to MS, considering various parameters across different time periods. While acknowledging the complexity and resource allocation required for such efforts, these are crucial elements for informed decision-making. In the broader context, the findings not only highlight the significance of nuanced policy approaches, taking into account sector-specific dynamics and the historical effectiveness of PaMs but also stress the ongoing importance of continuous refinement in reporting mechanisms, enhanced data quality, and the establishment of a robust monitoring framework. These measures are deemed essential for achieving accurate and reliable GHG emission projections across MS and timeframes.

Summary of conclusions and recommendations to improve quality-checking of reported information on GHG projections:

- Lack of completeness in reported proxies makes it difficult to identify proxies for all IPCC categories projected, thereby hampering the analysis and improvement of Quality Control activities at the category level within the ETC. Further guidance from the EEA and the ETC, along with improved reporting from Member States on drivers of relevant IPCC categories, can enhance understanding of projections and QC activities within the ETC.
- At its current status, improving category disaggregation in reporting GHG emissions does not add value to understanding MS projections, as specific models and parameters provided are either national totals or sectoral, rather than category-specific. Some reported parameters are not proxies, but direct activity data used to calculate emissions (i.e., activity data of the inventory). While this information is useful, it differs from other types of parameters considered proxies of emissions. Exploring a different type of analysis for these parameters and their relationship with GHGs, such as comparing interannual growths and trends of projected activity data against projected emissions, could be beneficial.
- Parameters reported under governance regulations do not include historical years, limiting empirical analysis possibilities at the ETC CM. Reporting this information would enable further modelling of the relationship between parameters and emissions in historical periods, thus improving projection models.
- Many reported proxies are non-stationary, suggesting either poor quality or non-usage in projections. Including further analysis in MS reports on how proxies are used in national models, along with the types of models used, could enhance understanding of projections and proxies, as well as quality checks developed by the ETC CM.

- The study proposes four additional checks within the ETC CM QC activities:
  - A check using identified proxies by IPCC category (at the granularity level proposed in this study) to identify MS outside the EU-27 range for the elasticity of the particular proxy (Part 1, step 3).
  - A check by IPCC category (at the granularity level proposed in this study) to assess the temporal evolution of proxies within the category (Part 1, step 4). Relevant changes will be cross-checked against PaMs reported with impact for the particular IPCC category. In the absence of PaMs, this will be interpreted as an issue in the model or the reporting of the MS.
  - A check for assessing the consistency of the With-Emission Measure (WEM) and Without-Emission Measure (WAM) with reported PaMs (Part 2, step 3).
  - A check for assessing the consistency of the difference between WAM and WEM scenarios with planned PaMs (Part 2, step 3).
- As discussed in part 3 of this report, there is a need to improve documentation from MS on the relationship between activity drivers and IPCC sectors in GHG projections and national models.

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Annex 1: Part 1. Assessment of GHG emission projections trends

A1.1 List of parameters (proxies) reported by MS

Table 12 Proxies reported by MS.

№	Selected parameters	MS Reporting: number	MS Reporting: %
1	Afforested land-Cropland converted to forest land	14	52%
2	Afforested land-Forest harvest removals for energy use	0	0%
3	Afforested land-Forest harvest removals for non-energy use	0	0%
4	Afforested land-Forest increment	4	15%
5	Afforested land-Grassland converted to forest land	17	63%
6	Afforested land-Other land converted to forest land	7	26%
7	Afforested land-Settlements converted to forest land	9	33%
8	Afforested land-Wetlands converted to forest land	10	37%
9	Agriculture	1	4%
10	Agriculture/ Forestry-Total	1	4%
11	Ammonia production	1	4%
12	Area of active peat extraction sites	1	4%
13	Area of cultivated organic soils	17	63%
14	Area of rewetted peat extraction sites	1	4%
15	Basic metal - ferro	1	4%
16	Basic metal - non ferro	1	4%
17	Broadleaf forest fires	1	4%
18	Ceramic production	1	4%
19	Chemical industry	1	4%
20	Chlorine production	1	4%
21	Coniferous forests fires	1	4%
22	Cropland converted to grassland, mineral soils	1	4%
23	Cropland converted to grassland, organic soils	1	4%
24	Cropland converted to other land	1	4%
25	Cropland converted to settlements, mineral soils	1	4%
26	Cropland converted to settlements, organic soils	1	4%
27	Cropland remaining cropland, average SOC stock	1	4%
28	Cropland, remaining cropland, organic soils	1	4%
29	Data Centre Median Demand installed capacity	1	4%
30	Deforested land-Forest land converted to cropland	12	44%
31	Deforested land-Forest land converted to grassland	13	48%
32	Deforested land-Forest land converted to other land	9	33%
33	Deforested land-Forest land converted to settlements	17	63%
34	Deforested land-Forest land converted to wetlands	13	48%
35	Disposable income	1	4%
36	Disposable income of households	4	15%
37	Electricity prices by type of using sector	1	4%
38	Electricity prices-Industry	8	30%
39	Electricity prices-Residential	9	33%
40	Electricity prices-Tertiary	7	26%
41	Enefit280 oil shale plants	1	4%
42	Ethyleen production	1	4%
43	EU ETS carbon price	24	89%
44	Exchange rates EURO	4	15%
45	Exchange rates US DOLLAR	4	15%
46	Fertilizer industry	1	4%
47	Final energy consumption - Agriculture and Forestry-Total	19	70%
48	Final energy consumption - All sectors-Derived heat	12	44%
49	Final energy consumption - All sectors-Electricity	16	59%
50	Final energy consumption - All sectors-Natural gas	17	63%

Nº	Selected parameters	MS Reporting: number	MS Reporting: %
51	Final energy consumption - All sectors-Oil	17	63%
52	Final energy consumption - All sectors-Other	16	59%
53	Final energy consumption - All sectors-Renewables	15	56%
54	Final energy consumption - All sectors-Solids	15	56%
55	Final energy consumption - All sectors-Thereof ambient heat	7	26%
56	Final energy consumption - All sectors-Total	19	70%
57	Final energy consumption - Industry-Electricity	14	52%
58	Final energy consumption - Industry-Heat	12	44%
59	Final energy consumption - Industry-Natural gas	16	59%
60	Final energy consumption - Industry-Oil	16	59%
61	Final energy consumption - Industry-Other	16	59%
62	Final energy consumption - Industry-Renewables	15	56%
63	Final energy consumption - Industry-Solids	15	56%
64	Final energy consumption - Industry-Total	19	70%
65	Final energy consumption - Other	2	7%
66	Final energy consumption - Residential-Electricity	15	56%
67	Final energy consumption - Residential-Heat	12	44%
68	Final energy consumption - Residential-Natural gas	17	63%
69	Final energy consumption - Residential-Oil	17	63%
70	Final energy consumption - Residential-Other	6	22%
71	Final energy consumption - Residential-Renewables	16	59%
72	Final energy consumption - Residential-Solids	12	44%
73	Final energy consumption - Residential-Total	20	74%
74	Final energy consumption - Tertiary-Electricity	14	52%
75	Final energy consumption - Tertiary-Heat	12	44%
76	Final energy consumption - Tertiary-Natural gas	16	59%
77	Final energy consumption - Tertiary-Oil	16	59%
78	Final energy consumption - Tertiary-Other	6	22%
79	Final energy consumption - Tertiary-Renewables	14	52%
80	Final energy consumption - Tertiary-Solids	10	37%
81	Final energy consumption - Tertiary-Total	19	70%
82	Final energy consumption - Transport-Electricity	18	67%
83	Final energy consumption - Transport-freight transport	4	15%
84	Final energy consumption - Transport-international aviation	7	26%
85	Final energy consumption - Transport-Natural gas	17	63%
86	Final energy consumption - Transport-Oil	19	70%
87	Final energy consumption - Transport-Other	11	41%
88	Final energy consumption - Transport-passenger transport	5	19%
89	Final energy consumption - Transport-Renewables	17	63%
90	Final energy consumption - Transport-Solids	3	11%
91	Final energy consumption - Transport-Total	20	74%
92	Final energy consumption-Derived heat	1	4%
93	Final energy consumption-Electricity	1	4%
94	Final energy consumption-Gas	1	4%
95	Final energy consumption-Oil	1	4%
96	Final energy consumption-Other	1	4%
97	Final energy consumption-Renewable energy	1	4%
98	Final energy consumption-Solids	1	4%
99	Final energy consumption-Thereof ambient heat	1	4%
100	Final energy consumption-Total	1	4%
101	Final non-energy consumption	12	44%
102	Food & beverage industry	1	4%
103	Forest available for wood supply with additional protective measures (excluding water protection forests on banks)	1	4%
104	Forest land converted to grassland, organic soils	1	4%
105	Forest land converted to settlements, organic soils	1	4%
106	Forest land remaining forest land, organic soils	1	4%
107	Forest land remaining forest land, share of drained areas from organic soils	1	4%
108	Forest not available for wood supply	1	4%

Nº	Selected parameters	MS Reporting: number	MS Reporting: %
109	Freight transport - heavy trucks	1	4%
110	Freight transport - light trucks	1	4%
111	Freight transport tonnes - kilometres - rail	1	4%
112	Freight transport tonnes - kilometres - road	1	4%
113	Freight transport tonnes - kilometres (all modes)	1	4%
114	Freight transport tonnes-kilometres-All modes	14	52%
115	Freight transport tonnes-kilometres-Domestic aviation	3	11%
116	Freight transport tonnes-kilometres-Domestic navigation	11	41%
117	Freight transport tonnes-kilometres-International aviation	3	11%
118	Freight transport tonnes-kilometres-Rail	14	52%
119	Freight transport tonnes-kilometres-Road - total	16	59%
120	Fuel inputs to other conversion processes	9	33%
121	Fuel inputs to thermal power generation-Gas	1	4%
122	Fuel inputs to thermal power generation-Natural gas	14	52%
123	Fuel inputs to thermal power generation-Oil	15	56%
124	Fuel inputs to thermal power generation-Solids	14	52%
125	Fuel inputs to thermal power generation-Total	14	52%
126	Glass production	1	4%
127	goat population	1	4%
128	Grassland converted to cropland, mineral soils	1	4%
129	Grassland converted to cropland, organic soils	1	4%
130	Grassland converted to forest land, organic soils	1	4%
131	Grassland converted to other land	1	4%
132	Grassland converted to settlements, mineral soils	1	4%
133	Grassland converted to settlements, organic soils	1	4%
134	Grassland converted to wetlands	1	4%
135	Grassland remaining grassland, organic soils	1	4%
136	Grassland remaining grassland, share of drained areas from organic soils	1	4%
137	Gross domestic product (GDP)-Constant prices	1	4%
138	Gross domestic product (GDP)-Real growth rate	1	4%
139	Gross domestic product-Constant prices	21	78%
140	Gross domestic product-Real growth rate	17	63%
141	Gross electricity generation-Natural gas	20	74%
142	Gross electricity generation-Natural gas (including derived gases)	1	4%
143	Gross electricity generation-Nuclear	11	41%
144	Gross electricity generation-Nuclear energy	1	4%
145	Gross electricity generation-Oil	17	63%
146	Gross electricity generation-Oil (incl. refinery gas)	1	4%
147	Gross electricity generation-Other fuels (hydrogen, methanol)	12	44%
148	Gross electricity generation-Renewables	20	74%
149	Gross electricity generation-Solids	19	70%
150	Gross electricity generation-Total	20	74%
151	Gross floor area - commercial buildings	1	4%
152	Gross floor area - education	1	4%
153	Gross floor area - hospitals	1	4%
154	Gross floor area - office buildings	1	4%
155	Gross floor area - other buildings	1	4%
156	Gross inland consumption by fuel type source-Crude oil and petroleum products	1	4%
157	Gross inland consumption by fuel type source-Derived heat	6	22%
158	Gross inland consumption by fuel type source-Electricity	16	59%
159	Gross inland consumption by fuel type source-Natural gas	21	78%
160	Gross inland consumption by fuel type source-Nuclear	9	33%
161	Gross inland consumption by fuel type source-Nuclear energy	1	4%
162	Gross inland consumption by fuel type source-Oil	19	70%
163	Gross inland consumption by fuel type source-Other	7	26%
164	Gross inland consumption by fuel type source-Renewables	20	74%
165	Gross inland consumption by fuel type source-Solid fossil fuels	1	4%
166	Gross inland consumption by fuel type source-Solids	18	67%
167	Gross inland consumption by fuel type source-Total	18	67%

Nº	Selected parameters	MS Reporting: number	MS Reporting: %
168	Gross inland consumption by fuel type source-Waste	11	41%
169	Gross value added-Agriculture	10	37%
170	Gross value added-Construction	10	37%
171	Gross value added-Energy sector	8	30%
172	Gross value added-Industry	13	48%
173	Gross value added-Services	11	41%
174	Gross value added-Total	11	41%
175	Harvested wood products-Gains of Harvested wood products	11	41%
176	Harvested wood products-Half-life - Paper	15	56%
177	Harvested wood products-Half-life - Sawn wood	15	56%
178	Harvested wood products-Half-life - Wood panels	15	56%
179	Harvested wood products-Losses of Harvested wood products	11	41%
180	Heat generation from combined heat and power plants, including industrial waste heat	14	52%
181	Heat generation from thermal power generation	11	41%
182	Herbaceous grassland fires	1	4%
183	horse population	1	4%
184	Household size	16	59%
185	Households	1	4%
186	Index of produced paper and paperboard volume to industrial roundwood production	1	4%
187	Index of produced sawnwood volume to industrial roundwood production	1	4%
188	Index of produced semi-chemical wood pulp volume to industrial roundwood production	1	4%
189	Index of produced wood-based panels volume to industrial roundwood production	1	4%
190	Indigenous Production by fuel type-Natural gas	9	33%
191	Indigenous Production by fuel type-Nuclear	6	22%
192	Indigenous Production by fuel type-Oil	8	30%
193	Indigenous Production by fuel type-Renewable energy sources	1	4%
194	Indigenous Production by fuel type-Renewables	12	44%
195	Indigenous Production by fuel type-Solids	6	22%
196	Indigenous Production by fuel type-Total	12	44%
197	Indigenous Production by fuel type-Waste and other	8	30%
198	Industrial waste deposited, biodegradable origin	1	4%
199	Industrial waste generation, biodegradable origin	1	4%
200	Industry	1	4%
201	Industry energy consumption-Total	1	4%
202	Industry-Electricity	1	4%
203	Industry-Gas	1	4%
204	Industry-Heat	1	4%
205	Industry-Oil	1	4%
206	Industry-Other	1	4%
207	Industry-Renewable energy	1	4%
208	Industry-Solids	1	4%
209	International (wholesale) fuel import prices-Coal	23	85%
210	International (wholesale) fuel import prices-Crude Oil	24	89%
211	International (wholesale) fuel import prices-Natural gas	24	89%
212	International aviation (bunker fuels)	1	4%
213	International shipping (bunker fuels)	1	4%
214	Livestock-Dairy cattle	25	93%
215	Livestock-Non-dairy cattle	25	93%
216	Livestock-Pig	25	93%
217	Livestock-Poultry	25	93%
218	Livestock-Sheep	25	93%
219	Managed cropland-Cropland converted to wetland, settlement or other land (excl. forest land)	16	59%
220	Managed cropland-Cropland remaining cropland	18	67%
221	Managed cropland-Grassland, wetland, settlement or other land converted to cropland	16	59%
222	Managed forest land-Forest harvest removals for energy use	7	26%
223	Managed forest land-Forest harvest removals for non-energy use	12	44%
224	Managed forest land-Forest increment	8	30%
225	Managed forest land-Forest land remaining forest land	18	67%

№	Selected parameters	MS Reporting: number	MS Reporting: %
226	Managed grassland-Cropland, wetland, settlement or other land, converted to grassland	15	56%
227	Managed grassland-Grassland converted to wetland, settlement or other land	16	59%
228	Managed grassland-Grassland remaining grassland	18	67%
229	Managed wetland-Settlement or other land, converted to wetland	6	22%
230	Managed wetland-Wetland converted to settlement or other land	8	30%
231	Managed wetland-Wetland remaining wetland	15	56%
232	Methanol production	1	4%
233	Milk yield	1	4%
234	Municipal solid waste (MSW) generation	1	4%
235	Municipal solid waste (MSW) going to landfills	1	4%
236	Municipal solid waste (MSW)-Generation	18	67%
237	Municipal solid waste (MSW)-Landfills	20	74%
238	National retail fuel prices-Coal - households	3	11%
239	National retail fuel prices-Coal - industry	4	15%
240	National retail fuel prices-Coal, industry	1	4%
241	National retail fuel prices-Diesel oil - households	7	26%
242	National retail fuel prices-Diesel oil - industry	7	26%
243	National retail fuel prices-Diesel oil - transport	7	26%
244	National retail fuel prices-Diesel oil - transport private	3	11%
245	National retail fuel prices-Diesel oil - transport public	2	7%
246	National retail fuel prices-Diesel oil, households	1	4%
247	National retail fuel prices-Diesel oil, industry	1	4%
248	National retail fuel prices-Diesel oil, transport	1	4%
249	National retail fuel prices-Gasoline - transport	7	26%
250	National retail fuel prices-Gasoline - transport private	3	11%
251	National retail fuel prices-Gasoline - transport public	2	7%
252	National retail fuel prices-Gasoline, transport	1	4%
253	National retail fuel prices-Natural gas - households	7	26%
254	National retail fuel prices-Natural gas - industry	6	22%
255	National retail fuel prices-Natural gas, households	1	4%
256	National retail fuel prices-Natural gas, industry	1	4%
257	Net imports Electricity	18	67%
258	Nitrogen fixed by N- fixing crops	11	41%
259	Nitrogen in crop residues returned to soils	20	74%
260	Nitrogen input from application of manure	24	89%
261	Nitrogen input from application of synthetic fertilizers	23	85%
262	Number of appartments	1	4%
263	Number of cooling degree days (CDD)	7	26%
264	Number of electricity-powered heavy duty vehicles	1	4%
265	Number of electricity-powered light commercial vehicles	1	4%
266	Number of electricity-powered passenger cars	1	4%
267	Number of heating degree days (HDD)	14	52%
268	Number of heavy duty vehicles	1	4%
269	Number of households	18	67%
270	Number of hydrogen-powered vehicles	1	4%
271	Number of Landing and Take-Off cycle - domestic aviation	1	4%
272	Number of Landing and Take-Off cycle - international aviation	1	4%
273	Number of light commercial vehicles	1	4%
274	Number of other houses	1	4%
275	Number of passenger cars	1	4%
276	Number of passenger- kilometres - rail	1	4%
277	Number of passenger- kilometres - road-Of which buses	1	4%
278	Number of passenger- kilometres - road-Of which motorcycles	1	4%
279	Number of passenger- kilometres - road-Of which private cars	1	4%
280	Number of passenger- kilometres (all modes)	1	4%
281	Number of passenger-kilometres-All modes	13	48%
282	Number of passenger-kilometres-Domestic aviation	7	26%
283	Number of passenger-kilometres-Domestic navigation	2	7%
284	Number of passenger-kilometres-International aviation	6	22%

Nº	Selected parameters	MS Reporting: number	MS Reporting: %
285	Number of passenger-kilometres-Rail	14	52%
286	Number of passenger-kilometres-Road - buses	11	41%
287	Number of passenger-kilometres-Road - motorcycles	10	37%
288	Number of passenger-kilometres-Road - private cars	15	56%
289	Number of passenger-kilometres-Road - public transport	10	37%
290	Number of passenger-kilometres-Road - total	12	44%
291	Number of terraced houses	1	4%
292	Other industry	1	4%
293	Other land converted to grassland	1	4%
294	Passenger road transport	1	4%
295	Petroter oil shale plants	1	4%
296	Population	25	93%
297	Primary aluminum production	1	4%
298	Production of horticultural peat	1	4%
299	Public transport - busses	1	4%
300	rabbit population	1	4%
301	Remaining fuel demand transport	1	4%
302	Residential-Electricity	1	4%
303	Residential-Gas	1	4%
304	Residential-Heat	1	4%
305	Residential-Oil	1	4%
306	Residential-Renewable energy	1	4%
307	Residential-Solids	1	4%
308	Residential-Total	1	4%
309	Salt production	1	4%
310	Service sector	1	4%
311	Service sector (including data centres)	1	4%
312	Settlements converted to forest land, organic soils	1	4%
313	Settlements converted to grassland	1	4%
314	Share of CH4 recovery in total CH4 generation from landfills	18	67%
315	Shrubland fires	1	4%
316	Steel production	1	4%
317	Tertiary-Electricity	1	4%
318	Tertiary-Gas	1	4%
319	Tertiary-Heat	1	4%
320	Tertiary-Oil	1	4%
321	Tertiary-Renewable energy	1	4%
322	Tertiary-Total	1	4%
323	The share of closed storage tanks from swine liquid manure storages	1	4%
324	The share of closed storage tants from cattle's liquid manure storages	1	4%
325	The share of lagoons with floating cover from swine's liquid manure storages	1	4%
326	The share of lagoons with natural crust from cattle's liquid manure storages	1	4%
327	The share of ring storage tanks with floating cover from swine's liquid manure storages	1	4%
328	The share of ring storage tanks with natural crust from cattle's liquid manure storages	1	4%
329	Total felling volume	1	4%
330	Transport	1	4%
331	Transport-Electricity	1	4%
332	Transport-Gas	1	4%
333	Transport-Oil	1	4%
334	Transport-Other	1	4%
335	Transport-Renewable energy	1	4%
336	Transport-thereof freight transport (when available)	1	4%
337	Transport-thereof international aviation	1	4%
338	Transport-thereof passenger transport (when available)	1	4%
339	Transport-Total	1	4%
340	Urea in milk	1	4%
341	Waste incineration	1	4%
342	Waste processing industry	1	4%
343	Wetlands converted to forest land, organic soils	1	4%

Nº	Selected parameters	MS Reporting: number	MS Reporting: %
344	Wetlands converted to grassland	1	4%

A1.2 Temporal evolution of proxies

Table 13 Temporal evolution sector 1.A.1. Proxy: Gross domestic product-Constant prices

Country Code	2021	2021-2030	2030-2040	2040-2050
SE	0.04	-0.18	-2.17	0.00
LT	-1.88	-0.94	0.00	0.00
PL	-0.38	-0.37	-2.77	0.00
DK	14.67	-136.05	-1.19	0.00
CZ	1.72	2.09	-2.86	-0.11
BG	0.12	0.29	-9.93	0.00
IT	1.82	1.52	-0.95	-0.01
IE	-4.38	-3.52	0.72	-0.03
CY	1.36	1.46	-1.15	-0.07
LV	0.08	-0.47	-2.94	-0.03
ES	-0.26	0.19	-1.38	0.00
NL	0.71	-2.47	-1.00	-0.01
EL	2.79	-1.13	-1.10	0.00
DE	1.50	0.59	-4.13	0.01
PT	1.45	-2.63	-2.30	-0.02
HR	0.17	0.21	-0.90	-0.01
EE	0.13	0.60	-1.37	-0.01
RO	1.48	1.94	0.83	-0.07
AT	0.31	0.50	-0.65	0.00

Table 14 Temporal evolution sector 1.A.2. Proxy: EU ETS carbon Price

Country Code	2021	2021-2030	2030-2040	2040-2050
SE	-0.03	-0.08	-0.57	-0.17
LT	-0.02	-0.04	-0.07	-0.07
PL	-0.03	-0.06	-0.22	0.00
DK	-0.06	-0.13	-0.91	0.00
CZ	0.00	-0.01	-0.03	-0.01
BG	0.02	-0.08	-0.27	0.00
IT	-0.02	-0.04	-0.07	0.05
IE	-0.12	-0.12	-0.26	-0.05
CY	-0.04	-0.05	-0.04	-0.08
LV	-0.05	-0.06	-0.76	-0.13
ES	0.10	0.09	-0.05	0.15
NL	-0.01	-0.12	-0.10	-0.43
EL	-0.03	-0.05	-0.29	0.00
DE	-0.04	-0.22	-1.10	-0.56
PT	0.21	0.17	-0.14	0.15
HR	-0.04	-0.09	-0.17	-0.30
EE	0.01	0.02	0.12	0.11
RO	0.06	0.10	0.23	0.21
AT	0.01	0.01	0.09	0.00

Table 15 Temporal evolution sector 1.A.3. Proxy: Gross domestic product-Constant prices

Country Code	2021	2021-2030	2030-2040	2040-2050
SE	0.86	1.52	-3.20	-0.04
LT	0.38	0.39	-1.50	-0.02
PL	0.04	0.06	-0.16	0.00
DK	0.21	0.33	-4.11	0.00
CZ	0.55	0.77	-0.74	-0.02
BG	-0.08	-0.08	-0.82	0.00
IT	0.34	0.08	-0.44	-0.01
IE	0.09	0.09	-2.23	-0.04
CY	0.08	0.18	-6.46	-0.11
LV	-0.10	-0.18	-2.20	-0.04
ES	-0.05	-0.11	-0.20	0.00
NL	-0.12	-0.04	-1.15	-0.01
EL	-0.21	-0.31	-0.71	0.00
DE	0.19	0.40	-4.78	-0.09
PT	-0.07	0.21	-2.37	-0.04
HR	-0.17	-0.07	-1.27	-0.03
EE	-0.04	-0.03	-3.99	-0.09
RO	-0.45	-0.62	0.98	0.01
AT	0.09	0.17	-2.68	-0.02

Table 16 Temporal evolution sector 1.A.4. Proxy: Gross domestic product-Constant prices

Country Code	2021	2021-2030	2030-2040	2040-2050
SE	1.56	1.50	-0.63	-0.02
LT	0.36	0.41	-0.17	0.00
PL	-0.04	-0.08	-0.33	0.00
DK	4.01	-4.48	-0.82	0.00
CZ	-0.45	-0.16	-0.65	-0.04
BG	0.14	0.20	-0.95	0.00
IT	0.52	0.59	-0.54	-0.01
IE	0.75	0.72	-1.47	0.00
CY	0.39	1.23	-1.09	-0.03
LV	0.18	0.23	-1.59	-0.03
ES	0.44	0.63	-0.25	0.00
NL	0.29	0.45	-1.04	-0.01
EL	0.50	0.71	-0.86	0.00
DE	0.46	0.73	-3.95	-0.03
PT	0.12	0.16	-0.70	-0.01
HR	-0.05	-0.01	-0.31	-0.01
EE	0.03	0.04	-0.20	0.00
RO	-0.04	-0.05	0.28	0.01
AT	0.60	0.67	-0.92	0.00

Table 17 Temporal evolution sector 2. Proxy: Gross domestic product-Constant prices

Country Code	2021	2021-2030	2030-2040	2040-2050
SE	-0.23	-0.47	-2.09	0.00
LT	0.06	-0.32	-0.47	0.00
PL	-0.05	-0.10	0.07	0.00
DK	0.62	-0.15	-0.43	0.00
CZ	0.17	0.26	-0.37	0.00
BG	-0.05	-0.13	-0.46	0.00
IT	-0.67	-0.67	-0.62	0.02
IE	-0.09	-0.06	0.38	0.01
CY	0.27	0.29	-0.01	0.00
LV	0.26	-0.41	-0.20	0.00
ES	-0.13	-0.13	-5.62	-0.02
NL	0.07	-0.62	-0.66	0.01
EL	0.42	0.39	0.00	0.00
DE	0.33	0.40	-3.31	0.00
PT	0.55	0.72	-0.85	-0.01
HR	0.19	0.26	-0.84	0.00
EE	0.39	0.55	-2.00	0.00
RO	-0.66	-0.93	0.12	0.00
AT	0.45	-0.10	-0.03	0.00

Table 18 Temporal evolution sector 3. Proxy: Gross domestic product-Constant prices

Country Code	2021	2021-2030	2030-2040	2040-2050
SE	0.12	0.20	-0.19	0.00
LT	0.04	0.18	-0.19	0.00
PL	-0.02	0.21	-0.12	0.00
DK	0.29	0.38	-0.28	0.00
CZ	-0.06	-0.05	-0.21	0.00
BG	-0.19	-0.29	0.70	0.00
IT	0.06	0.09	-0.38	0.00
IE	-0.10	-0.10	0.10	0.00
CY	0.08	0.05	-0.09	0.00
LV	0.07	0.05	-0.09	0.00
ES	0.12	0.18	-0.12	0.00
NL	0.09	0.11	-0.08	0.00
EL	-0.19	-0.28	0.63	0.00
DE	0.16	0.21	-0.21	0.00
PT	-0.07	-0.09	0.08	0.00
HR	-0.01	0.02	-0.18	0.00
EE	-0.54	0.64	-0.03	0.00
RO	-0.29	-0.34	0.45	0.00
AT	0.19	0.19	0.05	0.00

Table 19 Temporal evolution sector 3.A. Proxy: Livestock-Poultry

Country Code	2021	2021-2030	2030-2040	2040-2050
SE	-0.10	-0.77	-0.26	-0.71
LT	-0.27	-0.78	-0.14	0.00
PL	0.12	-0.17	-0.10	0.00
DK	-0.49	-0.52	-0.90	0.00
CZ	0.26	0.26	0.41	0.27
BG	0.73	1.01	1.43	0.00
IT	0.06	-0.06	-1.29	-0.62
IE	0.29	0.30	0.42	0.46
CY	0.60	0.63	0.05	0.05
LV	-0.40	-0.40	-0.62	-0.12
ES	-0.36	-0.47	-0.48	-0.54
NL	-0.19	-0.20	-0.10	-0.35
EL	1.18	1.46	1.94	0.00
DE	-0.35	-0.57	-0.69	-0.07
PT	0.10	0.17	0.30	0.36
HR	-0.90	-1.11	-0.92	-0.26
EE	0.67	1.13	-0.02	0.00
RO	-0.51	-0.48	-0.07	-0.39
AT	-0.39	-0.68	0.20	-0.67

Table 20 Temporal evolution sector 3.B. Proxy: Livestock-Poultry

Country Code	2021	2021-2030	2030-2040	2040-2050
SE	0.09	-0.83	-0.69	-0.44
LT	-1.04	-2.48	-1.68	-4.16
PL	1.81	3.48	-0.45	0.00
DK	-1.20	-1.51	-1.94	0.00
CZ	0.22	0.37	0.36	0.09
BG	0.80	1.01	1.43	0.00
IT	-0.96	-1.30	-1.59	0.53
IE	-0.20	-0.26	0.01	0.02
CY	-1.77	-1.91	-1.31	-1.43
LV	-0.61	-0.70	-0.98	-0.52
ES	-0.52	-0.84	-0.34	-0.41
NL	-0.24	-0.28	-0.22	-0.35
EL	1.18	1.46	1.94	0.00
DE	-0.41	-0.58	-0.45	-0.04
PT	0.22	0.30	0.26	0.30
HR	-0.02	0.26	0.21	0.47
EE	0.45	0.83	0.02	0.03
RO	-0.76	-0.73	-0.56	-1.05
AT	-0.44	-0.78	0.00	-0.92

A1.3 Regression table: Elasticities of parameters vs sectoral GHG projections

Table 21 Regression table for sector 1. Energy (only first 10 sub-parameters for exemplification)

Country code	Livestock - Poultry	Gross domestic product - Real growth rate	Population	International (wholesale) fuel import prices - Natural gas	Final energy consumption - All sectors - Total	Final energy consumption - All sectors - Electricity	Final energy consumption - Transport - Other	Number of households	Final energy consumption - Industry - Total	Final energy consumption - Tertiary - Renewables
AT	0.962	0.189	-7.129	0.350	5.781	-1.045	-0.163	-4.293	-3.506	-0.639
BE	-4.337		-2.990		2.982	-1.926		-1.828	-2.966	-0.195
BG	-6.047		-0.051	-3.647	0.349	15.080	5.363	-0.048		
CY	-0.368			0.051		-1.869				
CZ	-3.926		24.834	0.018			1.079	-7.817		-0.310
DE	-84.986	-0.011	149.471	1.056	5.755	-3.206	-0.181		8.326	-1.391
DK	16.224	-1.726	-22.030	3.060	13.738	-2.694	-0.334		3.822	-1.559
EE	-0.849	0.436	47.136	0.979	4.039	-0.388			-7.793	-1.557
EL	-1.882		7.162	-0.943	-8.763			8.974	-5.718	
ES	1.994		-2.047	0.401						
FI	26.520	1.326	85.467	-3.615	36.994			-56.334	-29.074	
FR	-0.005	-0.605	-19.191	0.001	3.287	-1.775	-0.127	-3.776	5.517	-2.428
HR	-2.865	0.950	2.354	-3.779	2.209	-1.703		-3.304	3.481	-0.434
HU		0.676	10.724	1.757	2.746	-0.861	-0.319		-1.510	2.293
IE	-1.443	-0.123	-2.568	0.427	-2.716	-0.640		-1.846	-1.638	-0.298
IT	-15.227		4.775	0.838				-13.394		
LT	-13.677	0.322	1.860				-0.117		-4.460	-2.816
LU	-1.580	0.502	-1.484	0.462	2.965	-1.236		-1.294	5.209	
LV	-101.056	0.835	8.024	0.594	4.276	-2.934	-0.068	11.807	-9.994	0.834
MT	-0.259	-0.162								
NL	0.000		-6.740	3.138	-1.230	-0.301		-5.903	-0.160	-1.216
NO	-3.342		-9.566							
PL	-2.428	0.567	7.008	-1.314	-5.008			-2.837	-7.707	
PT	-97.533	2.021	0.038	-3.540	3.363	-3.522	-0.110	-9.857	-3.198	-1.259
RO		-0.054	-0.476	0.001	0.291				0.000	
SE	-3.318		-8.405	3.942	-10.015	-1.430		-8.246	-2.311	
SI	0.000		2.600	-0.217				-1.143		
SK	0.895	0.153	3.332	0.486			-0.041	-1.128		

Annex 2: Part 2. Assessment of the consistency between policies and measures and emission scenarios

A2.1 Regression results

Table 22 Estimation results of the regression analysis for Sector 1.A.1 Energy Industries.

Country Code	$PAMst$	$PAMlt$	$lnGDPpc$	Constant	R^2	Significance F	Minimum of 5 PaMs over at least 5 years?
AT	-0.008	-0.052 ***	0.925	-0.132	0.695	0.0001	Yes
BE	0.003	-0.010 ***	-0.351	13.898	0.899	0.0000	Yes
BG	-0.034 ***	-0.082 ***	0.443 ***	6.512	0.853	0.0000	Yes
CY	-0.014 **	-0.002	1.503 ***	-6.909	0.783	0.0000	Yes
CZ	-0.013 *	-0.034 ***	0.666 ***	4.843	0.861	0.0000	Yes
DE	-0.015	-0.042 ***	1.925 **	-7.022	0.694	0.0001	Yes
DK	-0.020 *	-0.073 ***	0.156	8.629	0.935	0.0000	Yes
EE	0.003	-0.069 ***	0.571 **	4.111	0.698	0.0001	Yes
EL	-0.032 **	-0.075 ***	0.206	9.076	0.869	0.0000	Yes
ES	-0.037 ***	-0.037 ***	1.410 **	-2.561	0.868	0.0000	Yes
FI	-0.019	-0.048 ***	1.302	-3.233	0.731	0.0000	Yes
FR	-0.002	-0.015 ***	0.582	5.007	0.826	0.0000	Yes
HR	-0.028 ***	-0.028 ***	0.066	8.157	0.757	0.0000	No
HU	-0.010	0.004	-1.335 ***	22.154	0.777	0.0000	No
IE	-0.023 ***	-0.016 ***	-0.101	10.821	0.942	0.0000	Yes
IT	-0.018 ***	-0.025 ***	2.072 ***	-9.368	0.965	0.0000	Yes
LT	-0.028	0.000 ***	-0.816 ***	15.869	0.740	0.0000	No
LU	-0.285 **	-0.084	7.286 **	-76.653	0.576	0.0018	No
LV	0.013 **	-0.020 ***	-0.373 ***	11.063	0.856	0.0000	Yes
MT	-0.299 ***	-0.078 **	-0.595 **	13.363	0.953	0.0000	No
NL	-0.012	-0.009	0.347	7.484	0.651	0.0004	Yes
PL	-0.007 **	-0.022 ***	0.145 *	10.819	0.874	0.0000	Yes
PT	-0.026	-0.035 ***	1.129	-1.035	0.606	0.0010	Yes
RO	-0.029 **	-0.042 ***	0.085	9.968	0.927	0.0000	Yes
SE	0.001	-0.033 ***	0.607	2.899	0.542	0.0035	Yes
SI	0.005	-0.023 ***	0.684 **	2.155	0.798	0.0000	Yes
SK	-0.003 *	-0.003 ***	-0.665 ***	15.481	0.919	0.0000	Yes

Note: ***, ** and * denotes statistical significance of at least 99%, 95% and 90% respectively. The dependent variable is defined as the natural logarithm of the annual GHG emissions in kt CO_2-eq.

Table 23 **Estimation results for the regression analysis for Sector 1.A.2 Manufacturing Industries and Construction.**

Country	$PAMst$	$PAMlt$	$lnGDPpc$	Constant	R^2	Significance F	Minimum of 5 PaMs over at least 5 years?
AT	-0.008	-0.014 **	0.815 ***	0.719	0.364	0.0478	Yes
BE	0.003	-0.011 ***	-0.962	19.924	0.873	0.0000	Yes
BG	0.022	0.168 **	-1.722 ***	23.141	0.616	0.0008	No
CY	0.009	-0.054 ***	1.185 **	-5.197	0.654	0.0003	Yes
CZ	-0.029	-0.032	-1.099 *	20.251	0.783	0.0000	Yes
DE	-0.014 **	-0.007	0.782 **	3.601	0.354	0.0541	Yes
DK	-0.046 **	-0.058 ***	0.817	-0.099	0.695	0.0001	Yes
EE	-0.017	-0.062 **	0.107	5.851	0.534	0.0040	Yes
EL	-0.110 ***	-0.133 ***	0.547 **	4.024	0.930	0.0000	Yes
ES	-0.033	-0.027	1.149	-0.579	0.574	0.0019	Yes
FI	-0.038 ***	-0.052 ***	0.999 ***	-0.974	0.969	0.0000	Yes
FR	-0.019 ***	-0.007 **	-0.104	12.194	0.872	0.0000	Yes
HR	-0.038 ***	-0.016	0.245	5.788	0.438	0.0181	No
HU	0.025 **	0.029 **	-0.778 *	15.471	0.398	0.0312	No
IE	-0.021 ***	-0.020 ***	0.641 ***	1.792	0.887	0.0000	Yes
IT	-0.036 ***	-0.036 ***	3.143 ***	-20.951	0.936	0.0000	Yes
LT	0.000 ***	0.000 ***	0.126	5.992	0.093	0.6342	No
LU	0.007	-0.078 ***	-0.120	8.571	0.602	0.0011	No
LV	-0.007	-0.044 ***	-0.140	8.271	0.774	0.0000	Yes
MT	0.233	0.062	-1.031	13.757	0.156	0.3970	No
NL	0.001	-0.005	-0.046	10.746	0.231	0.2038	Yes
PL	0.081 ***	0.040	-0.686 ***	16.582	0.809	0.0000	No
PT	-0.036 ***	-0.033 ***	1.449 ***	-4.883	0.857	0.0000	Yes
RO	-0.014	-0.021 **	-0.111	10.742	0.671	0.0002	Yes
SE	0.017	-0.067 ***	-0.807	17.838	0.880	0.0000	Yes
SI	-0.028 ***	-0.039 ***	0.926 ***	-1.160	0.917	0.0000	Yes
SK	-0.002	-0.003 *	-0.293 **	11.775	0.761	0.0000	Yes

Note: ***, ** and * denotes statistical significance of at least 99%, 95% and 90% respectively. The dependent variable is defined as the natural logarithm of the annual GHG emissions in kt CO_2-eq.

Table 24 Estimation results for the regression analysis for Sector 1.A.3 Transport.

Country	$PAMst$	$PAMlt$	$lnGDPpc$	Constant	R^2	Significance F	Minimum of 5 PaMs over at least 5 years?
AT	-0.030	-0.057 ***	2.179 ***	-12.851	0.523	0.0048	No
BE	-0.003	-0.006 **	1.251 **	-2.827	0.333	0.0692	Yes
BG	-0.012	0.000 ***	0.727 ***	2.726	0.923	0.0000	No
CY	0.005	-0.036 ***	1.069 ***	-3.071	0.805	0.0000	Yes
CZ	0.000	0.014	0.522 *	4.646	0.792	0.0000	Yes
DE	-0.024	0.000 ***	-0.199	14.080	0.221	0.2255	No
DK	-0.024	-0.020	0.701	2.056	0.176	0.3375	Yes
EE	-0.001	-0.016 **	0.485 ***	3.105	0.835	0.0000	Yes
EL	-0.044 *	-0.025	1.165 ***	-1.484	0.914	0.0000	No
ES	-0.009 ***	-0.007 ***	1.713 ***	-5.749	0.944	0.0000	Yes
FI	-0.008	-0.037 ***	0.612 ***	3.014	0.764	0.0000	Yes
FR	-0.014 ***	-0.004 **	0.585 **	5.834	0.814	0.0000	Yes
HR	0.004	-0.012 ***	1.010 ***	-0.692	0.958	0.0000	Yes
HU	-0.007	-0.002	0.941 ***	0.681	0.689	0.0001	No
IE	0.012	-0.036 ***	0.434 **	4.787	0.378	0.0401	Yes
IT	-0.006 *	-0.039 ***	1.035 ***	1.083	0.967	0.0000	Yes
LT	0.042 **	0.000	0.542 ***	3.405	0.924	0.0000	No
LU	-0.009	-0.044 **	1.619 ***	-9.775	0.527	0.0045	Yes
LV	-0.021	-0.054 **	0.593 ***	2.626	0.664	0.0003	Yes
MT	0.002	0.020	0.357 ***	2.803	0.789	0.0000	No
NL	-0.030 ***	0.007	-0.298	13.572	0.643	0.0004	Yes
PL	0.008	-0.025	1.465 ***	-2.644	0.956	0.0000	Yes
PT	-0.024 ***	-0.025 ***	1.571 ***	-5.459	0.772	0.0000	Yes
RO	0.013	0.006	0.466 ***	5.433	0.933	0.0000	Yes
SE	-0.015	-0.040 ***	0.637 **	3.253	0.815	0.0000	Yes
SI	0.031 ***	-0.003	1.157 ***	-2.910	0.889	0.0000	Yes
SK	-0.003	-0.003	0.372 ***	5.362	0.602	0.0011	Yes

Note: ***, ** and * denotes statistical significance of at least 99%, 95% and 90% respectively. The dependent variable is defined as the natural logarithm of the annual GHG emissions in kt CO2-eq.

Table 25 Estimation results for the regression analysis for Sector 1.A.4 Other Sectors.

Country	$PAMst$	$PAMlt$	$lnGDPpc$	Constant	R^2	Significance F	Minimum of 5 PaMs over at least 5 years?
AT	-0.025 **	-0.060 ***	-0.526	15.082	0.956	0.0000	Yes
BE	-0.001	-0.005 **	-0.865	19.341	0.811	0.0000	Yes
BG	-0.020	-0.031	-0.419 ***	11.343	0.656	0.0003	No
CY	-0.007	-0.030 ***	0.304	3.457	0.601	0.0011	Yes
CZ	0.006	0.000	-0.700 ***	16.286	0.813	0.0000	Yes
DE	-0.007	0.000	-1.416 **	26.709	0.799	0.0000	Yes
DK	-0.044 ***	-0.061 ***	-0.218	11.379	0.862	0.0000	Yes
EE	0.005	-0.003	-0.018	6.758	0.018	0.9579	Yes
EL	-0.066 *	-0.143 ***	1.100 **	-1.113	0.858	0.0000	Yes
ES	0.003	-0.014 *	0.709 *	3.483	0.293	0.1094	Yes
FI	-0.025 **	-0.027 ***	-0.315	12.107	0.937	0.0000	Yes
FR	-0.006	-0.011 ***	-0.462	16.337	0.867	0.0000	Yes
HR	-0.017 *	-0.010	-0.238	10.471	0.483	0.0093	No
HU	0.000	0.005	-0.817 **	17.115	0.498	0.0073	No
IE	0.010 *	-0.016 ***	0.222 *	6.920	0.763	0.0000	Yes
IT	-0.008	-0.002	0.592	5.303	0.382	0.0382	Yes
LT	0.000 ***	0.000 ***	0.165 ***	5.736	0.350	0.0569	No
LU	0.016 *	-0.027	-0.454	12.580	0.288	0.1143	No
LV	-0.004	-0.013 ***	0.180 **	5.755	0.418	0.0238	Yes
MT	0.175 *	0.098	-1.610 **	20.733	0.304	0.0966	No
NL	0.003	-0.021 **	0.047	10.127	0.604	0.0010	Yes
PL	-0.106 ***	-0.008	0.208 ***	9.127	0.758	0.0000	No
PT	-0.044 ***	-0.034 ***	1.147 *	-2.416	0.819	0.0000	Yes
RO	-0.015	-0.008	0.399 ***	5.802	0.489	0.0085	Yes
SE	0.033	-0.066 ***	-3.442 ***	45.179	0.952	0.0000	Yes
SI	-0.025 **	-0.046 ***	-0.290	10.855	0.935	0.0000	Yes
SK	-0.003 *	-0.003 **	-0.242 **	11.006	0.786	0.0000	Yes

Note: ***, ** and * denotes statistical significance of at least 99%, 95% and 90% respectively. The dependent variable is defined as the natural logarithm of the annual GHG emissions in kt CO2-eq.

Table 26 **Estimation results for the regression analysis for Sector 2. Industrial Processes and Product Use.**

Country	$PAMst$	$PAMlt$	$lnGDPpc$	Constant	R^2	Significance F	Minimum of 5 PaMs over at least 5 years?
AT	0.040 *	-0.034 *	1.029 ***	-1.197	0.795	0.0000	No
BE	-0.011	-0.075 ***	0.132	8.809	0.817	0.0000	Yes
BG	0.000 ***	0.000 ***	-0.662 ***	14.314	0.462	0.0127	No
CY	0.000 ***	0.000 ***	0.565	1.256	0.084	0.6733	No
CZ	-0.007	-0.064 **	0.529 **	4.655	0.554	0.0028	No
DE	-0.023 ***	-0.023 ***	0.850 *	2.413	0.864	0.0000	Yes
DK	-0.090 ***	-0.198 ***	1.583 ***	-8.809	0.956	0.0000	No
EE	-0.058 *	-0.099 ***	0.785 *	-0.790	0.423	0.0224	Yes
EL	-0.053	-0.196 ***	0.066	8.897	0.693	0.0001	No
ES	-0.053 *	-0.133 ***	1.160 ***	-1.022	0.892	0.0000	No
FI	-0.024 **	-0.081 ***	1.156 ***	-3.426	0.788	0.0000	No
FR	-0.035 *	-0.037	-0.331	14.407	0.766	0.0000	Yes
HR	-0.015	-0.004	0.589 ***	2.647	0.546	0.0032	No
HU	0.025	0.128	-0.432	12.855	0.118	0.5317	No
IE	-0.243 **	-0.010	-0.228	10.595	0.257	0.1580	No
IT	0.000 ***	0.000 ***	2.483 ***	-14.943	0.808	0.0000	No
LT	-0.012	-0.029	0.110	7.065	0.028	0.9181	No
LU	0.020 *	-0.051 ***	-0.185	8.668	0.693	0.0001	No
LV	0.000 ***	0.000 ***	1.352 ***	-6.165	0.669	0.0002	No
MT	-0.115	0.000 ***	5.206 ***	-46.720	0.736	0.0000	No
NL	-0.010	-0.115 *	-2.966 ***	40.827	0.773	0.0000	No
PL	0.009	-0.159 **	0.731 ***	3.525	0.665	0.0003	No
PT	-0.013	-0.035 ***	1.447 **	-5.154	0.446	0.0161	Yes
RO	-0.045	-0.029	-0.446	13.624	0.548	0.0031	No
SE	-0.088 *	-0.199 ***	1.265 **	-4.212	0.594	0.0013	No
SI	-0.094 ***	-0.105 ***	1.253 ***	-4.952	0.767	0.0000	No
SK	-0.152 **	-0.201 ***	0.304 **	6.367	0.460	0.0130	No

Note: ***, ** and * denotes statistical significance of at least 99%, 95% and 90% respectively. The dependent variable is defined as the natural logarithm of the annual GHG emissions in kt CO2-eq.

Table 27 Estimation results for the regression analysis for Sector 3. Agriculture.

Country	$PAMst$	$PAMlt$	$lnGDPpc$	Constant	R^2	Significance F	Minimum of 5 PaMs over at least 5 years?
AT	0.000 ***	0.000 ***	-0.130 *	10.269	0.225	0.2170	No
BE	-0.001	0.003	-0.666 ***	16.177	0.809	0.0000	No
BG	0.000 ***	0.000 ***	0.274 ***	6.223	0.442	0.0170	No
CY	-0.130 **	-0.053	0.108	5.180	0.247	0.1741	No
CZ	0.020 *	0.010	-0.250 **	11.337	0.263	0.1494	Yes
DE	0.000 ***	0.000 ***	-0.076	11.798	0.078	0.7004	No
DK	-0.004	-0.004	-0.031	9.777	0.390	0.0344	Yes
EE	0.004	0.011	0.411 ***	3.259	0.792	0.0000	No
EL	-0.013 *	-0.044 ***	-0.065	9.790	0.812	0.0000	No
ES	-0.015	-0.007	0.007	10.390	0.055	0.8022	No
FI	0.000	0.002	-0.059	9.382	0.161	0.3820	Yes
FR	-0.006 **	0.000	-0.406 **	15.432	0.720	0.0001	Yes
HR	-0.020 ***	-0.023 ***	0.102	7.125	0.571	0.0020	No
HU	-0.027	0.028	0.201	6.870	0.553	0.0028	No
IE	0.000 ***	0.000 ***	0.169 ***	8.112	0.494	0.0078	No
IT	-0.001	0.000 ***	0.656 **	3.689	0.362	0.0492	No
LT	0.000 ***	0.000 ***	0.124 ***	7.200	0.760	0.0000	No
LU	0.013	0.019 *	-0.439	11.389	0.174	0.3419	Yes
LV	0.011 ***	0.010 ***	0.180 ***	5.874	0.857	0.0000	Yes
MT	0.064	0.000 ***	-0.322 ***	7.670	0.553	0.0028	No
NL	0.000	0.000 ***	-0.242	12.400	0.156	0.3957	No
PL	0.003	0.003	0.023	10.168	0.210	0.2497	Yes
PT	-0.002	0.002	0.069	8.183	0.065	0.7584	Yes
RO	0.013	-0.011	-0.027	10.136	0.355	0.0535	Yes
SE	-0.002	-0.007	-0.219	11.183	0.680	0.0002	No
SI	-0.021 *	-0.036 ***	0.114	6.431	0.524	0.0048	No
SK	0.037	0.072 **	-0.438 ***	11.932	0.715	0.0001	No

Note: ***, ** and * denotes statistical significance of at least 99%, 95% and 90% respectively. The dependent variable is defined as the natural logarithm of the annual GHG emissions in kt CO_2-eq.

Table 28 Estimation results for the regression analysis for Sector 4. Land Use, Land-Use Change and Forestry.

Country	$PAMst$	$PAMlt$	$lnGDPpc$	Constant	R^2	Significance F	Minimum of 5 PaMs over at least 5 years?
AT	0.000 ***	0.000 ***	9.339 ***	-107.796	0.597	0.0012	No
BE	-0.147	0.267	7.571 **	-86.192	0.441	0.0172	No
BG	0.000 ***	0.000 ***	0.916 ***	-17.198	0.614	0.0009	No
CY	0.000 ***	0.000 ***	-0.892	3.456	0.087	0.6626	No
CZ	-0.347 *	0.096	1.709	-25.128	0.365	0.0472	No
DE	0.000 ***	0.000 ***	-3.366	26.441	0.293	0.1091	No
DK	-0.132	-0.433	5.357	-65.655	0.102	0.5973	No
EE	0.699 **	0.452 **	-0.424	-4.519	0.586	0.0015	No
EL	-0.099	-0.257	0.091	-8.718	0.027	0.9230	No
ES	-0.004	0.001	-0.469 **	-5.973	0.420	0.0233	Yes
FI	0.399 ***	0.462 ***	0.652	-17.054	0.703	0.0001	No
FR	0.072 *	0.069 **	-1.992	10.002	0.672	0.0002	Yes
HR	0.191 **	0.116	0.442	-12.913	0.492	0.0080	No
HU	0.175 **	0.172 *	-3.758 ***	26.321	0.692	0.0001	No
IE	0.000 ***	0.000 ***	0.146	-10.389	0.199	0.2752	No
IT	0.000 ***	0.000 ***	2.717 *	-38.307	0.190	0.2968	No
LT	0.000 ***	0.000 ***	-0.045	-8.415	0.049	0.8304	No
LU	-0.019	0.019	2.713	-37.237	0.402	0.0296	Yes
LV	-0.022	0.016	3.137 ***	-37.062	0.505	0.0065	No
MT	0.000 ***	0.000 ***	0.839	-9.407	0.226	0.2153	No
NL	0.078 **	0.178 ***	0.967 ***	-18.852	0.832	0.0000	No
PL	-0.098	-0.200	0.835	-17.984	0.222	0.2228	No
PT	0.099	0.518	-23.382 *	220.175	0.205	0.2607	No
RO	-0.072	0.026	-0.450 ***	-6.573	0.680	0.0002	No
SE	0.022	0.000 ***	0.663 *	-17.819	0.212	0.1013	No
SI	-0.510	0.316	2.653	-34.442	0.298	0.1030	No
SK	0.331 **	0.443 *	-0.071	-8.449	0.609	0.0010	No

Note: ***, ** and * denotes statistical significance of at least 99%, 95% and 90% respectively. The dependent variable is defined as the natural logarithm of the annual GHG emissions in kt CO2-eq.

Table 29 **Estimation results for the regression analysis for Sector 5. Waste.**

Country	*PAMst*	*PAMlt*	*lnGDPpc*	Constant	R^2	Significance F	Minimum of 5 PaMs over at least 5 years?
AT	-0.065 **	-0.182 ***	-1.494 **	23.734	0.931	0.0000	No
BE	-0.078	-0.252 ***	-5.065 ***	60.922	0.833	0.0000	No
BG	0.000 ***	0.000 ***	-0.338 ***	11.116	0.698	0.0001	No
CY	0.000 ***	0.000 ***	0.312	3.243	0.145	0.4353	No
CZ	0.042	-0.005	0.663 ***	2.118	0.788	0.0000	No
DE	-0.038	-0.050	-5.760 ***	69.634	0.935	0.0000	No
DK	0.021	-0.040	-0.107	8.321	0.393	0.0332	Yes
EE	-0.089 ***	-0.099 ***	-0.591 ***	11.875	0.905	0.0000	No
EL	-0.018	-0.018	0.096	7.635	0.099	0.6115	No
ES	-0.015	-0.035 ***	0.083	8.861	0.413	0.0256	No
FI	-0.105 ***	-0.193 ***	-0.657 **	15.473	0.961	0.0000	Yes
FR	-0.024 ***	-0.012 **	-0.526	15.507	0.828	0.0000	Yes
HR	-0.001	0.194 ***	0.489 ***	2.812	0.940	0.0000	No
HU	-0.026 ***	-0.016 **	-0.137	9.693	0.866	0.0000	Yes
IE	0.681 ***	0.000 ***	0.330	3.300	0.322	0.0202	No
IT	0.000 ***	0.000 ***	1.471 ***	-5.107	0.575	0.0019	No
LT	-0.121 **	-0.225 ***	-0.427 ***	11.209	0.933	0.0000	No
LU	-0.045 ***	-0.051 ***	-0.066	5.505	0.802	0.0000	No
LV	0.000 ***	0.000 ***	-0.331 ***	9.574	0.782	0.0000	No
MT	0.000 ***	0.000 ***	-0.063	5.679	0.029	0.9139	No
NL	0.000 ***	0.000 ***	-6.398 ***	76.486	0.851	0.0000	No
PL	-0.039	-0.069	-1.208 ***	20.188	0.976	0.0000	No
PT	-0.107 ***	-0.161 ***	0.073	8.147	0.956	0.0000	No
RO	0.010	-0.007	0.067	8.182	0.322	0.0786	Yes
SE	-0.046	0.035	-5.085 ***	61.887	0.847	0.0000	No
SI	-0.100 ***	-0.423 ***	-0.016	6.933	0.940	0.0000	No
SK	0.010	0.003	0.323 ***	4.411	0.925	0.0000	No

Note: ***, ** and * denotes statistical significance of at least 99%, 95% and 90% respectively. The dependent variable is defined as the natural logarithm of the annual GHG emissions in kt CO2-eq.

A2.2 Comparison of the reported and estimated GHG projections for WEM scenario

Figure 13 Comparison of GHG projections results for WEM scenario in sector 1.A.1 Energy Industries.

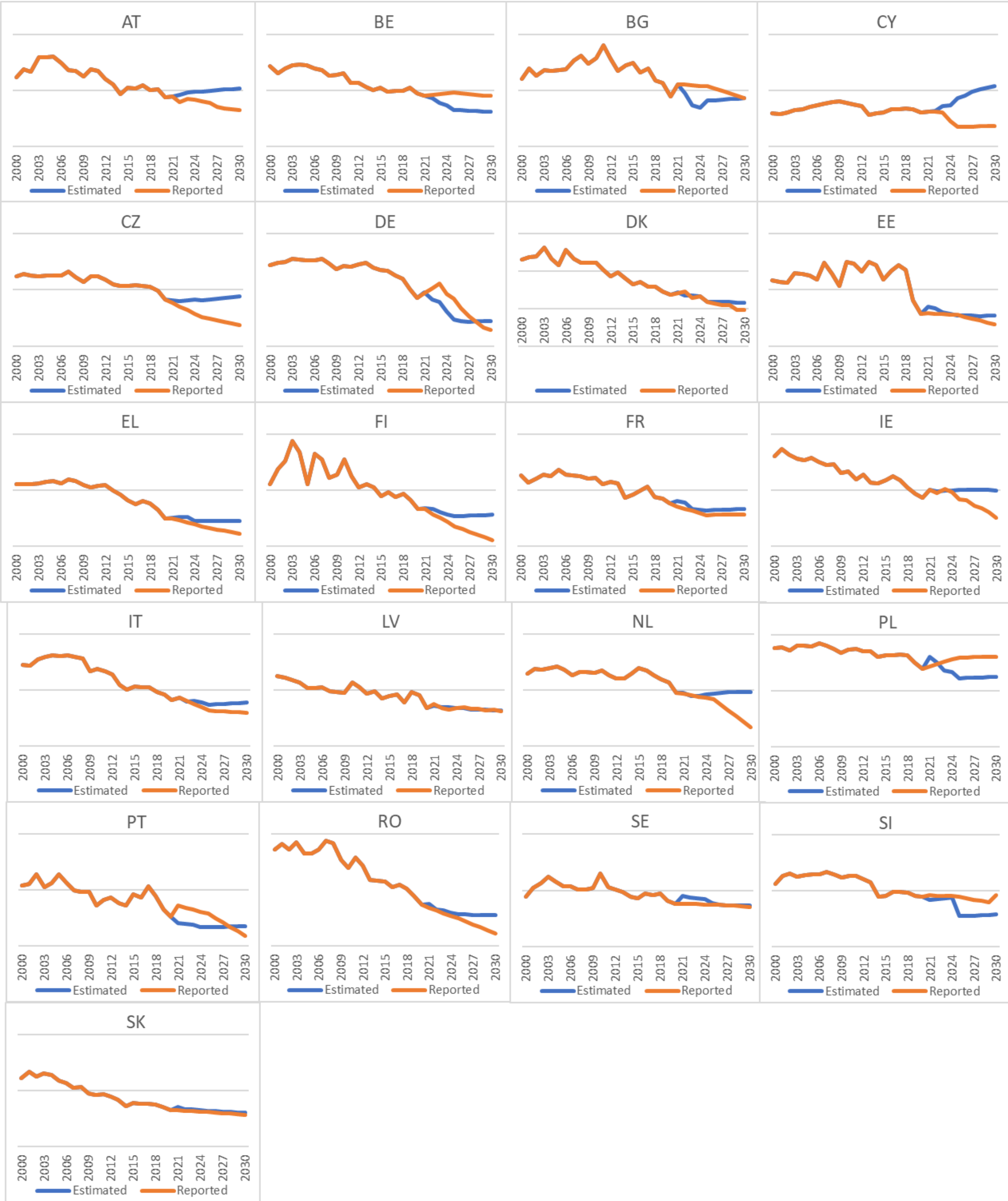


Figure 14 Comparison of GHG projections results for WEM scenario in sector 1.A.2 Manufacturing Industries and Construction.

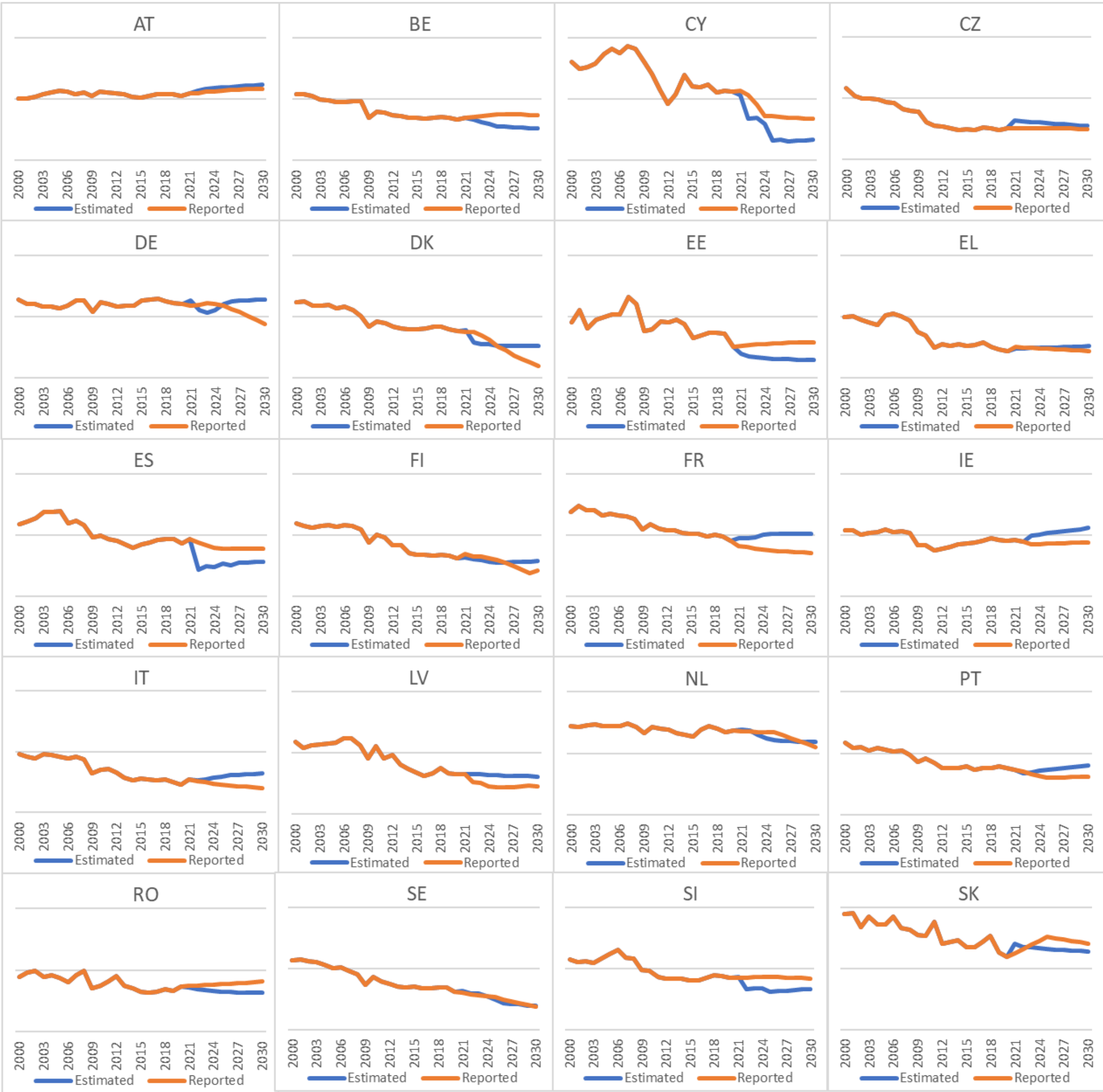


Figure 15 Comparison of GHG projections results for WEM scenario in sector 1.A.3 Transport.

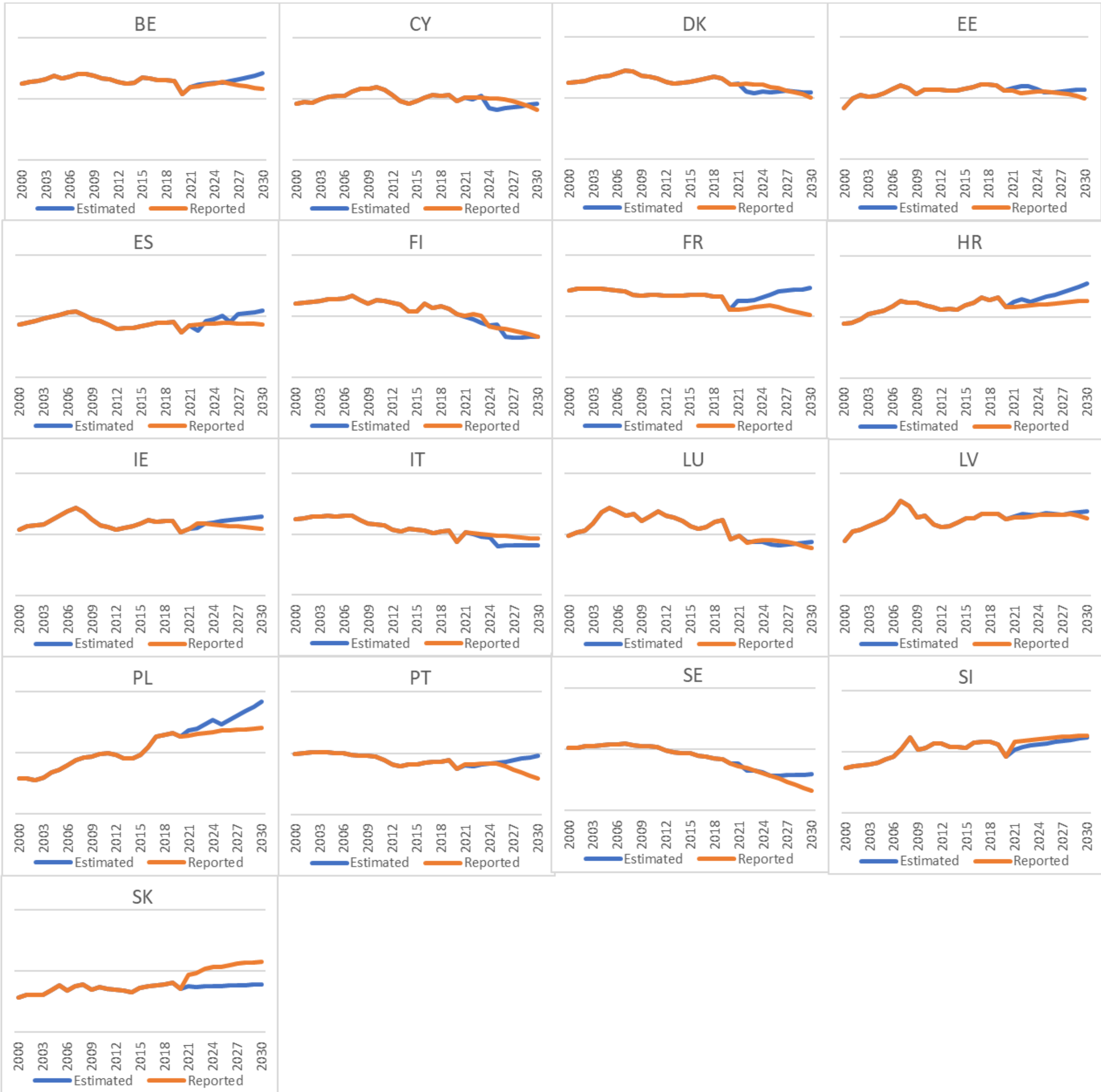


Figure 16 Comparison of GHG projections for WEM scenario of sector 1.A.4 Other Sectors.

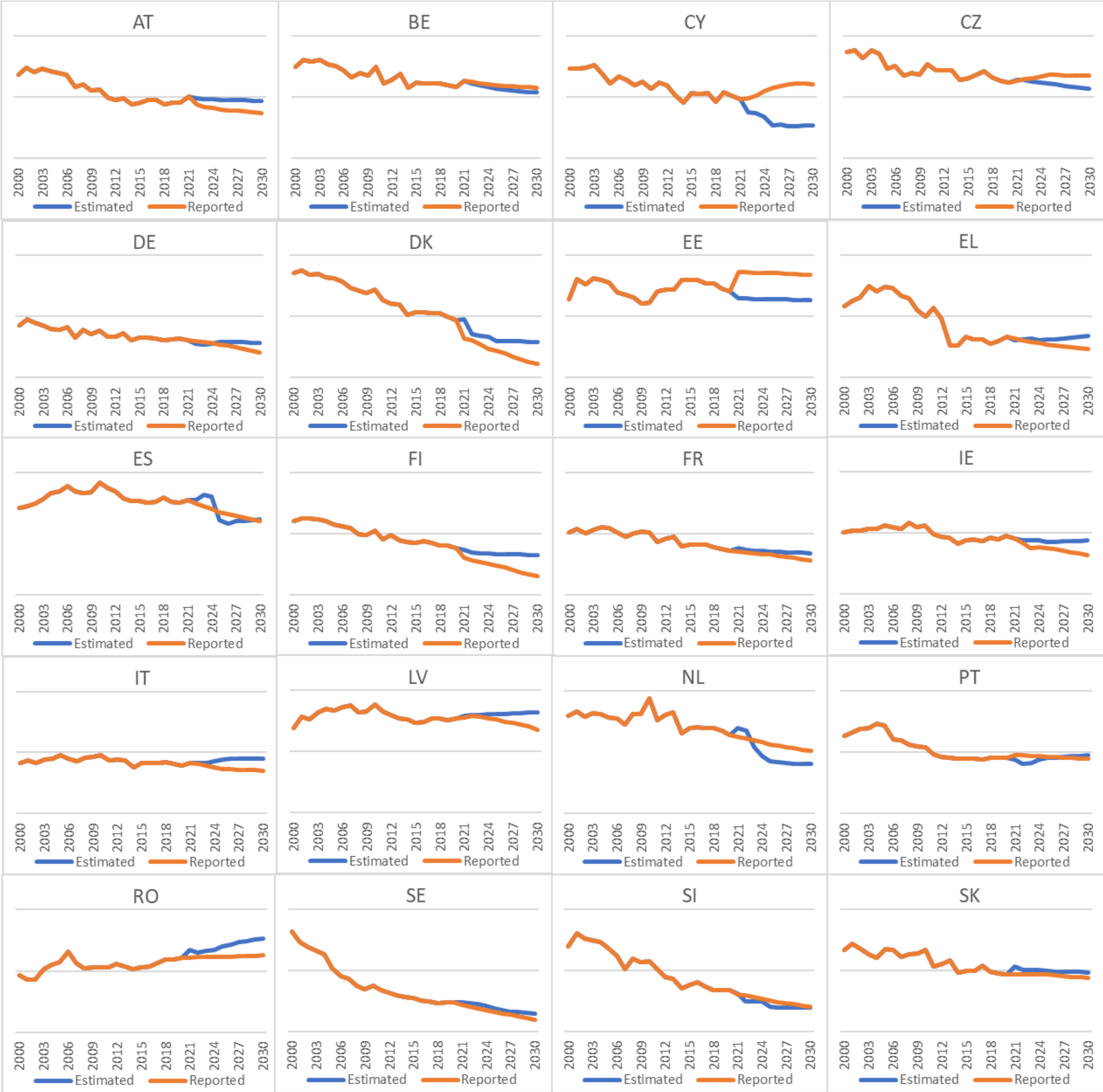


Figure 17 Comparison of GHG projections for WEM scenario of sector 2. Industrial Processes and Product Use.

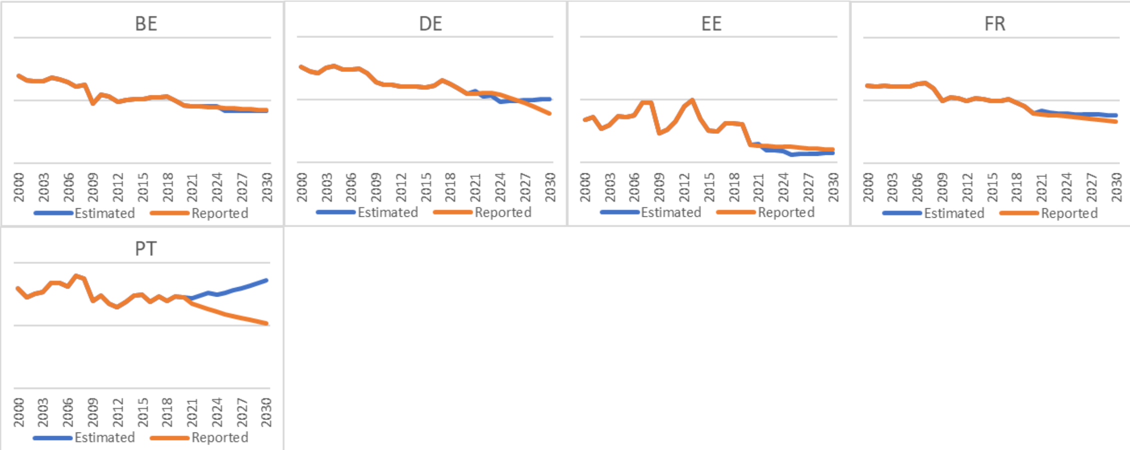


Figure 18 Comparison of GHG projections for WEM scenario of sector 3. Agriculture.

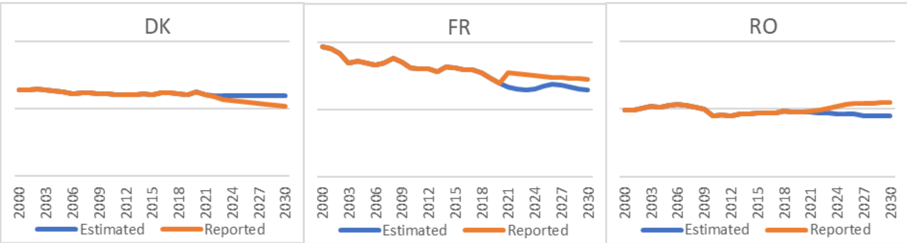
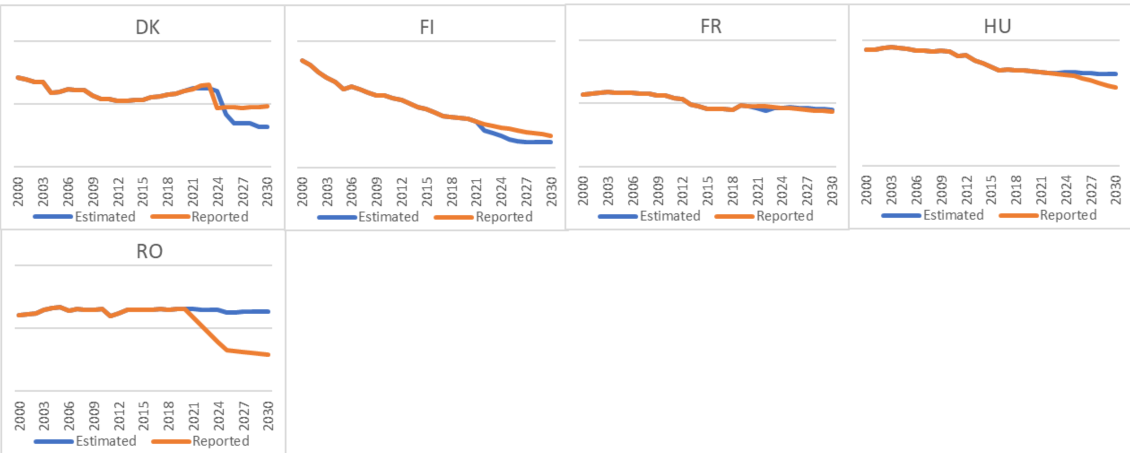


Figure 19 Comparison of GHG projections for WEM scenario of sector 5. Waste



Annex 3: Part 3. Qualitative assessment of drivers

A3.1 Review of projection reports

Table below presents the used activity drivers by each Member State in the 2023 reported GHG projections.

Table 30 Summary results of the reviewed methodology report.

Member State	Sector	Activity driver	Notes
AT	Energy	GDP [billion € 2020], GDP real growth rate [%], Population [1 000], Stock of dwellings [1 000], Heating degree days, Exchange rate [US$/€], International coal price [€ 2020/GJ], International oil price [€ 2020/GJ], International natural gas price [€ 2020/GJ], CO2 certificate price [€ 2020/t CO2]	The following models are used for the energy scenario: econometric input-output data (MIO-ES), domestic heating and domestic hot water supply (INVERT/EE-Lab), public electrical power and district heating supply (MIO ES), and energy demand and emissions of transport (NEMO & GEORG).
	Industry processes and product use		Expert judgment and respective gross value added
	Agriculture		PASMA is used for projection of activity level (animal livestock, crop yields, mineral fertilizer, agriculture area). Later PASMA is feed to ADAGIO and WIFO's input-output model to determine the economic impact of agricultural sector.
	LULUCF		Different models in combination with expert judgment are used for the projections: PASMA, CALDIS, and FOHOW2
	Waste		Expert judgment is used.
BE (Flemish region)	Energy	Projections for residential sector are based on degree days in the future, the share of new residences and the lifetime of existing installations. Projections for industry sector is based on industrial activity and energy efficiency (yearly growth rate per sector), the share of CHP per sector and the lifetime of installations. Electricity demand is the main driver for the projections of electricity.	A bottom-up model explaining energy consumption and emissions from activity variables mostly in physical unit and the main determining factors of the evolution of energy demand and emissions
	Road transport	vehicle fleet (number of vehicles per vehicle type, annual mileage per vehicle type), geographically explicit vehicle counts per road segment on the other hand (number of passing vehicles per road segment and the associated speed)	FASTRACE in combination with a traffic flow simulator (like VISUM) and emission factors (COPERT) is used for the projections of emissions from the road transport
BE (Walloon region)	Energy	Residential: growth in the number of households Commercial: employment growth Industry: economic activities (costs, temporal availability of new technologies, etc. Transport: passenger-kilometre and ton-kilometre, and energy used for other transport mode Electricity generation: electricity demand	Projections are made by using TIMES-Wal model
	Agriculture	livestock, agricultural area, fertilizer uses, etc.	An excel model
	Waste	the amount of total waste disposed, the recovery rate of landfill, CH4 and N2O emissions of wastewater handling, etc.	An excel model

Member State	Sector	Activity driver	Notes
BE (Brussels Capital Region)	Energy	Residential: population, dwelling size, climate conditions, renovation rate and Renovation characteristics Commercial: employment, surface, climate conditions, renovation rate and renovation characteristics Industry: energy intensity evolution Energy production: sources and Installations, efficiency, operation hours	A bottom-up excel-based model
	Transport	Historical survival curve of vehicle fleets combined with other constraints like LEZ exclusions, transport demand, etc.	Emissions and fuel consumption projections are done by means of COPERT IV model
BG	All	-	Projection is based on (B)EST model
CY	Energy	GDP, population, energy production projection data and energy consumption development, prices of fuels on the global market, carbon prices	Projections are based on to models: OSeMOSYS-Cyprus and Final energy demand projection model
	Agriculture		Projections are made based on trends in the main activity data like animal population cattle and swine population, amount of fertilizers applied to agricultural soils, and annual harvest and production
	LULUCF		Projections are made based on the observed trends and anticipation of gradually less intensive land use changes until 2050
	Waste	GDP, population, etc.	
CZ	Energy (including transport)	-	TIMES-CZ and COPERT models are used for the projections
	Industry processes and product use	-	Projections use the same methodology is used as for the National Inventory Report.
	Agriculture	-	Projections are made by IPCC methodology (IPCC guidelines for national GHG inventories) and the 2006 IPCC refinement (Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories)
	LULUCF	-	Projections are based on the observed trends, additional data from 2021, and anticipation of in general gradually. In addition, projections of emissions use a calibrated version of Operational Scale Carbon Budget Model of the Canadian Forest Service (CBM-CFS3).
	Waste	-	Projections use the same methodology is used as for the National Inventory Report.
DK	At the point of the review, Denmark has not provided their methodology report.		
EE	Energy	historical trends, long term real GDP growth rate, Shared Service Centre measures, Long-term strategy for building reconstruction scenarios, industry input, etc.	Balmorel model is used for the electricity generation projections
	Transport	-	Sybil baseline model and information from the ITF and TalTech reports are used the road transport projections
	Industrial processes and product use	Companies' production forecasts, population projection, the long-term real GDP growth rate, and expert judgements	

Member State	Sector	Activity driver	Notes
	Agriculture	-	Projections are done by means of the 2006 IPCC methodology and APM model
	LULUCF	-	Projections are based on a set of assumptions in combination with categories and methods described in the National Inventory Report
	Waste	-	Projections are based on the 2006 IPCC waste model
EL	Energy	GDP and population (as input to TIMES forecasting prices of energy commodities, CO2 prices, costs of energy technologies, and potential of indigenous energy sources. chronological curves of customer load and production of non-dispatchable power plants, expansion plan of power system (energy technology capacities, investments on power plants), and electricity demand are inputted to PropSim.	MARKAL-EFOM System (TIMES) in combination with PropSim is used
	Industry processes and product use	Energy projected to be consumed (energy consumption) by TIMES	
	Agriculture	Animal population, the quantities of synthetic nitrogen fertilizers applied on soils and agricultural crops production.	The rate of change of animal population and agricultural crops production are estimated based on the expected GDP change.
	Waste	-	Projections are based on the data provided by "National waste management plan 2020 – 2030".
	LULUCF	A set of land accounting categories with their underlying assumption are used. The categories are afforested land, deforestation land, managed forced land, managed cropland, managed grassland, and managed wetland.	Projections are based on activity data during the period of 1990 – 2020.
ES	At the time of the review, the provided methodology report by Spain was not written in English.		
FI		Population [Million inhabitants], Gross Domestic Product [Billion EUR, 2020 prices], Coal wholesale price [EUR/GJ LHV, 2020 prices for history, 2022 prices for the future], Crude oil wholesale price [EUR/GJ LHV, 2020 prices for history, 2022 prices for the future], Natural gas wholesale price [EUR/GJ LHV, 2020 prices for history, 2022 prices for the future], Emission allowance price [EUR/t nominal prices], Electricity, tax category I [cent/kWh, 2020 prices for history, 2022 prices for the future], Electricity, tax category II [cent/kWh, 2020 prices for history, 2022 prices for the future], Energy content component [EUR/MWh LHV, 2020 prices for history, 2022 prices for the future], Carbon dioxide component [EUR/t lifetime CO2 emissions, 2020 prices for history, 2022 prices for the future], Energy content component [EUR/MWh LHV, 2020 prices for history, 2022 prices for the future], Carbon dioxide component [EUR/t lifetime CO2 emissions, 2020 prices for history, 2022 prices for the future]	Projections are done based on modelling and assumption made by experts from different research fields in the "Carbon neutral Finland 2035" (project HIISI)
FR	At the time of the review, the provided methodology report by France was not written in English.		
HR		GDP (annual growth rate), population, coal prices, heavy fuel oil prices, gas prices	general economic parameters
	Energy	Total energy consumption (by energy carrier), total electricity generation (by energy carrier), Final energy consumption (by sub-sector type), Number of heating degree days,	Projections are made by using MAED and MESSAGE models

Member State	Sector	Activity driver	Notes
	Industrial processes and product use	Clinker production	A tabula calculator is used which is structured in accordance with the United Nations Framework Convention on Climate Change.
	Transport	Number of passenger kilometres, all modes, transport of goods, energy consumption in road transport	
	Agriculture	Dairy cattle, non-dairy cattle, sheep, goats, horses, mules/asses, swine, poultry, wheat, maize, potatoes, sugar beets, tobacco, sunflowers, rape seed, tomatoes, barley, oats, cabbages and other brassicas, garlic, onions, rye, sorghum, watermelons, soybeans, dry beans, dried fodder peas, lentils, dry peas, vetches, clover, alfalfa, applying nitrogen	A tabula calculator is used which is structured in accordance with the United Nations Framework Convention on Climate Change.
	LULUCF	Activity data suggested by the report are the parameters here	Projections are done based on the National Inventory Report
	Waste	Amount of generated solid waste, amount of landfilled solid waste, share of methane recovered/flared	A tabula calculator is used which is structured in accordance with the United Nations Framework Convention on Climate Change.
HU	Energy	GDP (average annual growth rate of real GDP), Fuel prices (oil price, natural gas price, coal price, biomass price), population, ETS prices (CO2 price for ETS1 and ETS2), discount rate (USD/EUR exchange rate and HUF/EUR exchange rate). Also, future demand (with econometric modelling are used).	Projections are made by means of HU-TIMES model
	Industrial processes and product use	-	Projections use the same methodology is used as for the National Inventory Report.
	Agriculture	-	AGMEMOD model and expert inputs are used for the projections
	Waste	-	Projections use the same methodology is used as for the National Inventory Report.
IS	Energy (excluding transport)	Fuel projections	Projections are based on “national inventory report” and fuel projections from “National Energy Authority”.
	Transport	Fuel projections, sybil baseline data	Projections are based on “national inventory report”, sibyl baseline (to run COPERT 5.6.1), and fuel projections from “National Energy Authority”.
	Industrial processes and product use	GDP, population, fuel projection, trends over the past years, activity data provided by the stakeholders, Legislation (import quota), mass balance to allocate imported amounts to different sectors	Projections are based on historical trends and expert judgement
	Agriculture	Linear extrapolation of historical trends, expert judgement,	Projections are based on historical trends and expert judgement
	LULUCF	Historical trend, model projecting C stock change, Government´s action plans, Linear extrapolation based on population projection 2022-2073	Projections are based on the historical inventory and Government’s Climate Action Plans, with the exception of the Settlements land category.
	Waste	Population projections, methane recovery projections from stakeholders, waste collection, export and landfill plans, mass-balance allocation, operation and operation permit of the gas and composting plant, methane collection communicated by operating company, operation permit of incinerator, projections for fish processing.	Projections are based on the historical inventory (“national inventory report”)
LT	No methodology report was detected that was submitted by LT at the time of the review.		

Member State	Sector	Activity driver	Notes
LV	Energy	Energy intensity or specific consumption and changes in them, the number of households, persons per households, household area, GDP, VA, private consumption, population, etc.	Projections are made based on TIMES-Latvia model
	Industry processes and product use	Macroeconomic parameters like value added and industrial production index, number of inhabitants, households and the number of freezing equipment used, the development of the service sector and the amount of stationary refrigeration used in it, changes in the number of vehicles in road transport, Gross domestic product	A top-down model
	Agriculture	-	Projections are made by experts' inputs
	LULUCF	-	Projections are based on Latvia's 2022 GHG inventory and different models like AGM
	Waste	Population, rate of national population served by modern centralized treatment plants, sewage sludge production based on its correlation with average annual amount of sewage sludge produced by a person	Projections are done by the 2006 IPCC Guidelines
MT	No methodology report was detected that was submitted by Malta at the time of the review.		
NL	Energy	Drivers for developments in the energy system, such as economic growth, population growth, behavioural change, fuel market information, and technological development	A series of models are used for the projections. NEOMES for the Dutch energy system
	Industrial processes and product use	The sectoral methodology was not identified in the report	
	Agriculture	-	The National Emission Model for Agriculture (NEMA) is used for the projections.
	LULUCF	-	the EFISCEN (European Forest Information Scenario) model is used for the projections.
	Waste	-	A spreadsheet model is used for the projections.
NO		-	Projections are based on a statistical model (SNOW)
PL	Energy	Energy intensity, macroeconomic and demographic scenario, fuel price, CO2 price, techno-economic assumptions for energy technologies, assumptions of energy policy	Projections of the final electricity and district heating demand are done in STEAM-PL model which later is feed to MESSAGE model to calculate optimal energy mix, electricity production in individual generation units, pollutant emissions, and averaged electricity production costs
	Remaining sectors	-	Projection methodology is aligned with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
PT	Energy including primary energy supply, electricity production, industry, residential, commercial and services, agriculture, forestry and fisheries (only the energy consumption) and transport	Demand for energy services, technologies' technical and economic characteristics for the base year and the future (e.g., efficiency, input/output rate, and operation and maintenance costs), availability of primary energy sources, policy restrictions (e.g., energy production targets or reduction of emissions).	TIMES_PT model is used for the projections
	Agriculture, forests and other land uses, Waste and wastewater and Fluorinated gases	-	Projections are made via an excel spreadsheet containing inventory methodologies
RO	Energy	Evolution of macroeconomic indicators (e.g., gross added value, and production of goods and services), consumption efficiency, changes	The National Commission for Strategy and Prognosis has determined the evolution of the

Member State	Sector	Activity driver	Notes
		of the energetic equipment's fleet, resource substitution	total energy demand and by types of energy resources
	Industrial processes and product use	Parameters like gross value added in industry, production structure by types of industrial processes	Projections using spreadsheet models.
	Agriculture	-	The sources of activity data are the National Institute for Statistics, the Ministry of Environment, Waters and Forests and the Ministry of Agriculture and Rural Development.
	LULUCF	Macroeconomic indicators	Projections are based on historical data coupled with macroeconomic indicators
	Waste	-	Projections are based on IPCC 2006 guidelines
SE	Energy	Electricity and heating production use the following inputs: demand in the sub-sectors, population development, taxes and other policy instruments, fuel prices and economic and technical development. EMEC's inputs are production factors such as labor, capacity and technological development	Different models and experts' opinions are used for projections in each sub-sector. TIMES-Nordic model is used for electricity and heating production. Projections on economic development are done by using general equilibrium model (EMEC)
	Industrial processes and product use	-	Projections are drawn from an excel-based trend analysis and experts' knowledge
	Agriculture	-	Projections are based on an economic equilibrium model developed by the Swedish Agricultural Sector model. The model uses assumptions on production and future agriculture policy.
	LULUCF	-	Heureka Regwise modelling is used for the projections.
	Waste	-	Projections are based on IPCC model and compared with field measurements. The IPCC model is based on quantities of landfilled waste from 1952, the organic content of waste, the gas potentials of different types of waste and emissions factors.
SI			
SK	Energy	Inputs such as prices of tradable fuels, EU ETS, capacity development, and energy market development are used	TIMES model in combination with CPS and Macro Economical Model (IEP) are used for the projections
	Transport		Using PRIMES in combination with TREMOVE for the projections
	Fugitive emissions		Projections are based on the 2006 IPCC methodology
	Agriculture	e.g., number of livestock	Projections are based on the 2006 IPCC methodology
	LULUCF		Exponential balance function or average value from historical data are used for projection of input parameters.
	Waste		Projections are based on demographic development and the 2006 IPCC guidelines

A.3.2 Activity drivers' coverage

Table 31 Activity drivers covered by the Member States

Country code	Part of projections	Not part of projections
AT	42	14
BE		33
BG	33	23
CH		9
CY	16	2
CZ	27	19
DE	23	31
DK	35	3
EE	68	10
EL	25	9
ES	22	
FI	29	3
FR	23	18
HR	39	13
HU	11	12
IE	23	16
IS	25	6
IT	11	15
LT	33	15
LU	30	14
LV	31	24
MT	10	9
NL	39	38
NO	7	13
PL	42	6
PT	25	1
RO	21	15
SE	10	43
SI	60	31
SK	8	17

A3.3 Similarity of commonly used activity drivers

Table 32 Frequency of similar activity drivers mentioned by the MS in Table 3: Reporting on parameters / variables for projections of GovReg.

Parameter	Country code	Count
Population	['AT' 'BE' 'BG' 'CH' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'FR' 'HR' 'HU' 'IE' 'IS' 'IT' 'LT' 'LU' 'LV' 'MT' 'NL' 'NO' 'PL' 'PT' 'RO' 'SE' 'SI' 'SK']	29
Gross domestic product	['AT' 'BG' 'CH' 'CY' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'FR' 'HR' 'HU' 'IE' 'IS' 'IT' 'LT' 'LU' 'LV' 'MT' 'NL' 'NO' 'PL' 'PT' 'RO' 'SE' 'SI' 'SK']	29
Livestock	['AT' 'BE' 'BG' 'CY' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'FR' 'HR' 'IE' 'IS' 'IT' 'LT' 'LU' 'LV' 'MT' 'NL' 'NO' 'PL' 'PT' 'SE' 'SI' 'SK']	27
Nitrogen input from application of manure	['AT' 'BE' 'BG' 'CY' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'FR' 'HR' 'IE' 'IS' 'IT' 'LT' 'LU' 'LV' 'MT' 'NL' 'NO' 'PL' 'PT' 'SE' 'SI' 'SK']	27
Nitrogen input from application of synthetic fertilizers	['AT' 'BE' 'BG' 'CY' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'FR' 'HR' 'IE' 'IS' 'IT' 'LT' 'LU' 'LV' 'MT' 'NL' 'NO' 'PL' 'SE' 'SI' 'SK']	26
International (wholesale) fuel import prices	['AT' 'BG' 'CH' 'CY' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'FR' 'HR' 'HU' 'IE' 'IT' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI' 'SK']	25
Municipal solid waste (MSW)	['AT' 'BE' 'BG' 'CY' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'FR' 'HR' 'IE' 'IS' 'IT' 'LT' 'LU' 'LV' 'MT' 'NO' 'PL' 'PT' 'SE' 'SI']	25
EU ETS carbon price	['AT' 'BG' 'CY' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'FR' 'HR' 'HU' 'IE' 'IT' 'LT' 'LV' 'NL' 'NO' 'PL' 'PT' 'RO' 'SE' 'SI' 'SK']	25
Area of cultivated organic soils	['AT' 'BE' 'BG' 'CY' 'DE' 'DK' 'EE' 'EL' 'FI' 'FR' 'HR' 'IE' 'IS' 'IT' 'LT' 'LU' 'LV' 'MT' 'NO' 'PL' 'PT' 'SE' 'SI' 'SK']	24
Nitrogen in crop residues returned to soils	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'FR' 'HR' 'IE' 'IS' 'IT' 'LT' 'LU' 'LV' 'MT' 'NO' 'PL' 'SE' 'SI' 'SK']	24
Freight transport tonnes-kilometres	['AT' 'BG' 'CY' 'CZ' 'DE' 'EL' 'ES' 'FR' 'HR' 'HU' 'IE' 'IS' 'IT' 'LT' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI' 'SK']	23
Final energy consumption - Transport	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'EE' 'EL' 'FI' 'FR' 'HR' 'HU' 'IE' 'LT' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI' 'SK']	23
Final energy consumption - All sectors	['AT' 'BE' 'BG' 'CY' 'CZ' 'DE' 'DK' 'EE' 'EL' 'FI' 'FR' 'HR' 'HU' 'IE' 'IS' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI']	23
Number of passenger-kilometres	['AT' 'BG' 'CY' 'CZ' 'DE' 'EL' 'ES' 'FR' 'HR' 'HU' 'IE' 'IT' 'LT' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI' 'SK']	22
Gross electricity generation	['AT' 'BE' 'BG' 'CY' 'CZ' 'DE' 'DK' 'EL' 'ES' 'FI' 'FR' 'HR' 'HU' 'LT' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI']	22
Managed forest land	['AT' 'BE' 'CZ' 'DE' 'DK' 'EE' 'EL' 'FI' 'FR' 'HR' 'IS' 'IT' 'LT' 'LV' 'MT' 'NL' 'NO' 'PL' 'RO' 'SE' 'SI' 'SK']	22
Afforested land	['AT' 'BE' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'HR' 'IS' 'IT' 'LT' 'LV' 'MT' 'NL' 'NO' 'PL' 'RO' 'SE' 'SI' 'SK']	22
Final energy consumption - Industry	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'EE' 'EL' 'FI' 'FR' 'HR' 'HU' 'IE' 'LT' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI']	22
Final energy consumption - Residential	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'EE' 'EL' 'FI' 'FR' 'HR' 'HU' 'IE' 'LT' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI']	22
Final energy consumption - Tertiary	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'EE' 'EL' 'FI' 'FR' 'HR' 'HU' 'IE' 'LT' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI']	22
Share of CH4 recovery in total CH4 generation from landfills	['AT' 'BE' 'BG' 'CY' 'CZ' 'DE' 'EE' 'EL' 'ES' 'FI' 'HR' 'IE' 'IT' 'LT' 'LU' 'LV' 'MT' 'NO' 'PL' 'PT' 'SE' 'SI']	22
Deforested land	['AT' 'BE' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'HR' 'IS' 'IT' 'LT' 'MT' 'NL''NO' 'PL' 'RO' 'SE' 'SI' 'SK']	21
Managed cropland	['AT' 'BE' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'HR' 'IS' 'IT' 'LT' 'MT' 'NL' 'NO' 'PL' 'RO' 'SE' 'SI' 'SK']	21
Managed grassland	['AT' 'BE' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FI' 'HR' 'IS' 'IT' 'LT' 'MT' 'NL' NO' 'PL' 'RO' 'SE' 'SI' 'SK']	21
Number of households	['AT' 'BE' 'BG' 'CZ' 'DE' 'EL' 'FI' 'FR' 'HR' 'IE' 'IS' 'IT' 'LU' 'LV' 'NL' 'NO' 'PL' 'PT' 'SE' 'SI' 'SK']	21
Gross inland consumption by fuel type source	['AT' 'BE' 'BG' 'CY' 'CZ' 'DE' 'DK' 'EE' 'EL' 'ES' 'FR' 'HR' 'HU' 'LT' 'LU' 'LV' 'NL' 'PL' 'PT' 'SE' 'SI']	21
Final energy consumption - Agriculture and Forestry	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'EE' 'EL' 'FI' 'FR' 'HR' 'HU' 'IE' 'LU' 'LV' 'NL' 'PL' 'PT' 'RO' 'SE' 'SI']	21

Parameter	Country code	Count
Net imports Electricity	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'EL' 'FI' 'FR' 'HR' 'HU' 'IE' 'LT' 'LU' 'LV' 'NL' 'PT' 'SE' 'SI' 'SK']	20
Nitrogen fixed by N- fixing crops	['AT' 'BE' 'BG' 'CY' 'CZ' 'DE' 'EL' 'FI' 'FR' 'HR' 'IE' 'IT' 'LT' 'LU' 'LV' 'PT' 'SE' 'SI' 'SK']	19
Managed wetland	['AT' 'BE' 'DE' 'DK' 'EL' 'FI' 'HR' 'IS' 'IT' 'LT' 'MT' 'NL' 'NO' 'PL' 'RO' 'SE' 'SI' 'SK']	18
Harvested wood products	['AT' 'CZ' 'DE' 'EE' 'EL' 'FI' 'FR' 'HR' 'IS' 'IT' 'LT' 'NL' 'NO' 'PL' 'RO' 'SE' 'SI' 'SK']	18
Household size	['AT' 'BE' 'BG' 'CZ' 'DE' 'EL' 'FR' 'HR' 'IE' 'IT' 'LU' 'LV' 'NL' 'NO' 'PL' 'PT' 'SE' 'SI']	18
Gross value added	['AT' 'BG' 'DE' 'DK' 'EL' 'FI' 'FR' 'HR' 'IE' 'IT' 'LU' 'LV' 'NL' 'PL' 'RO' 'SE' 'SI']	17
Indigenous Production by fuel type	['AT' 'BE' 'BG' 'DE' 'DK' 'FR' 'HR' 'IE' 'LT' 'LU' 'LV' 'NL' 'PL' 'PT' 'SE' 'SI']	16
Number of heating degree days (HDD)	['AT' 'BE' 'CH' 'CZ' 'DE' 'FR' 'HR' 'HU' 'IE' 'LU' 'LV' 'NL' 'PL' 'SE' 'SI' 'SK']	16
Fuel inputs to thermal power generation	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'FR' 'HR' 'HU' 'IE' 'LU' 'LV' 'NL' 'PL' 'SE' 'SI']	16
Heat generation from thermal power generation	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'FR' 'HR' 'HU' 'LT' 'LU' 'LV' 'NL' 'SE' 'SI']	15
Heat generation from combined heat and power plants, including industrial waste heat	['AT' 'BE' 'BG' 'CZ' 'DE' 'DK' 'FR' 'HR' 'HU' 'LU' 'LV' 'NL' 'PT' 'SE' 'SI']	15
Final non-energy consumption	['AT' 'BE' 'CZ' 'DE' 'DK' 'FR' 'HR' 'HU' 'LT' 'LV' 'NL' 'PL' 'SE' 'SI']	14
National retail fuel prices	['AT' 'BG' 'CY' 'DE' 'DK' 'FR' 'HR' 'LU' 'LV' 'NL' 'PL' 'SE' 'SI']	13
Fuel inputs to other conversion processes	['AT' 'BE' 'BG' 'DE' 'DK' 'FR' 'HR' 'IE' 'LV' 'NL' 'PL' 'SE' 'SI']	13
Number of cooling degree days (CDD)	['AT' 'CZ' 'DE' 'FR' 'HR' 'HU' 'IE' 'LV' 'NL' 'PL' 'SE' 'SI']	12
Electricity prices	['AT' 'BG' 'DE' 'DK' 'FR' 'HR' 'LU' 'LV' 'NL' 'PL' 'SE' 'SI']	12
Exchange rates EURO	['AT' 'BG' 'DE' 'HR' 'HU' 'IE' 'LV' 'NO' 'PL' 'SE' 'SI']	11
Exchange rates US DOLLAR	['AT' 'DE' 'HR' 'HU' 'IE' 'LV' 'NL' 'PL' 'RO' 'SE' 'SI']	11
Final energy consumption - Other	['AT' 'CZ' 'DE' 'FI' 'FR' 'HR' 'LV' 'PT' 'SE' 'SI']	10
Disposable income of households	['AT' 'DE' 'DK' 'HR' 'IE' 'LV' 'PL' 'SE' 'SI']	9
Industry	['NL' 'SI']	2
Transport	['NL' 'SI']	2
Electricity prices by type of using sector	['BG']	1
Energy reference area (total)	['CH']	1
Full-time equivalent (all sectors)	['CH']	1
Average day temperature	['CH']	1
Passenger cars	['CH']	1
Freight transport (road) and buses	['CH']	1
The share of lagoons with natural crust from cattle's liquid manure storages	['EE']	1
The share of ring storage tanks with natural crust from cattle's liquid manure storages	['EE']	1
The share of closed storage tants from cattle's liquid manure storages	['EE']	1
The share of lagoons with floating cover from swine's liquid manure storages	['EE']	1
The share of ring storage tanks with floating cover from swine's liquid manure storages	['EE']	1
The share of closed storage tanks from swine liquid manure storages	['EE']	1
Enefit280 oil shale plants	['EE']	1
Petroter oil shale plants	['EE']	1
Forest not available for wood supply	['EE']	1
Forest available for wood supply with additional protective measures (excluding water protection forests on banks)	['EE']	1
Total felling volume	['EE']	1
Forest land remaining forest land, organic soils	['EE']	1

Parameter	Country code	Count
Forest land remaining forest land, share of drained areas from organic soils	['EE']	1
Grassland converted to forest land, organic soils	['EE']	1
Wetlands converted to forest land, organic soils	['EE']	1
Settlements converted to forest land, organic soils	['EE']	1
Forest land converted to grassland, organic soils	['EE']	1
Forest land converted to settlements, organic soils	['EE']	1
Cropland, remaining cropland, organic soils	['EE']	1
Grassland converted to cropland, mineral soils	['EE']	1
Grassland converted to cropland, organic soils	['EE']	1
Cropland converted to settlements, mineral soils	['EE']	1
Cropland converted to settlements, organic soils	['EE']	1
Cropland converted to other land	['EE']	1
Grassland remaining grassland, organic soils	['EE']	1
Grassland remaining grassland, share of drained areas from organic soils	['EE']	1
Cropland converted to grassland, mineral soils	['EE']	1
Cropland converted to grassland, organic soils	['EE']	1
Wetlands converted to grassland	['EE']	1
Settlements converted to grassland	['EE']	1
Other land converted to grassland	['EE']	1
Grassland converted to wetlands	['EE']	1
Grassland converted to settlements, mineral soils	['EE']	1
Grassland converted to settlements, organic soils	['EE']	1
Grassland converted to other land	['EE']	1
Cropland remaining cropland, average SOC stock	['EE']	1
Area of active peat extraction sites	['EE']	1
Area of rewetted peat extraction sites	['EE']	1
Production of horticultural peat	['EE']	1
Index of produced sawnwood volume to industrial roundwood production	['EE']	1
Index of produced wood-based panels volume to industrial roundwood production	['EE']	1
Index of produced paper and paperboard volume to industrial roundwood production	['EE']	1
Index of produced semi-chemical wood pulp volume to industrial roundwood production	['EE']	1
Industrial waste generation, biodegradable origin	['EE']	1
Industrial waste deposited, biodegradable origin	['EE']	1
Coniferous forests fires	['ES']	1
Broadleaf forest fires	['ES']	1
Shrubland fires	['ES']	1
Herbaceous grassland fires	['ES']	1
Data Centre Median Demand installed capacity	['IE']	1
Methane recovery	['IS']	1
Number of vehicles - Gasoline	['IS']	1
Number of vehicles - Diesel	['IS']	1
Number of vehicles - CNG (bio)	['IS']	1
Number of vehicles - Electric	['IS']	1
Number of vehicles - Hydrogen	['IS']	1
Fish caught	['IS']	1
Number of Landing and Take-Off cycle - domestic aviation	['IT']	1
Number of Landing and Take-Off cycle - international aviation	['IT']	1
Number of passenger cars	['LT']	1
Number of electricity-powered passenger cars	['LT']	1
Number of light commercial vehicles	['LT']	1
Number of electricity-powered light commercial vehicles	['LT']	1
Number of heavy duty vehicles	['LT']	1
Number of electricity-powered heavy duty vehicles	['LT']	1

Parameter	Country code	Count
Number of hydrogen-powered vehicles	['LT']	1
Milk yield	['LU']	1
Urea in milk	['LU']	1
goat population	['MT']	1
rabbit population	['MT']	1
horse population	['MT']	1
Disposable income	['MT']	1
Steel production	['NL']	1
Primary aluminum production	['NL']	1
Ammonia production	['NL']	1
Ethyleen production	['NL']	1
Methanol production	['NL']	1
Chlorine production	['NL']	1
Salt production	['NL']	1
Glass production	['NL']	1
Ceramic production	['NL']	1
Waste inceneration	['NL']	1
Passenger road transport	['NL']	1
Freight transport - light trucks	['NL']	1
Freight transport - heavy trucks	['NL']	1
Public transport - busses	['NL']	1
International aviation (bunker fuels)	['NL']	1
International shipping (bunker fuels)	['NL']	1
Agriculture	['NL']	1
Service sector	['NL']	1
Number of appartments	['NL']	1
Number of terraced houses	['NL']	1
Number of other houses	['NL']	1
Gross floor area - education	['NL']	1
Gross floor area - hospitals	['NL']	1
Gross floor area - commercial buildings	['NL']	1
Gross floor area - office buildings	['NL']	1
Gross floor area - other buildings	['NL']	1
Basic metal - ferro	['NL']	1
Basic metal - non ferro	['NL']	1
Fertilizer industry	['NL']	1
Chemical industry	['NL']	1
Food & beverage industry	['NL']	1
Other industry	['NL']	1
Waste processing industry	['NL']	1
Remaining fuel demand transport	['NL']	1
Households	['NL']	1
Service sector (including data centres)	['NL']	1
Gross value added (GVA)- total	['SI']	1
Gross value added (GVA) - agriculture	['SI']	1
Gross value added (GVA)- construction	['SI']	1
Gross value added (GVA) - services	['SI']	1
Gross value added (GVA) - energy sector	['SI']	1
Gross value added (GVA) - industry	['SI']	1
Number of passenger- kilometres - domestic aviation	['SI']	1
Number of passenger- kilometres - international aviation	['SI']	1
Number of passenger- kilometres - domestic navigation	['SI']	1
Freight transport tonnes - kilometres - domestic aviation	['SI']	1
Freight transport tonnes - kilometres - international aviation	['SI']	1
Freight transport tonnes - kilometres - domestic navigation (inland waterways and national maritime)	['SI']	1
Exchange rates EURO (for non- EURO countries), if applicable	['SI']	1
Exchange rates US DOLLAR, if applicable	['SI']	1

Parameter	Country code	Count
Gross domestic product (GDP)	['SI']	1
Number of passenger- kilometres (all modes)	['SI']	1
Number of passenger- kilometres - road	['SI']	1
Number of passenger- kilometres - rail	['SI']	1
Freight transport tonnes - kilometres (all modes)	['SI']	1
Freight transport tonnes - kilometres - road	['SI']	1
Freight transport tonnes - kilometres - rail	['SI']	1
Final energy consumption	['SI']	1
Industry energy consumption	['SI']	1
Residential	['SI']	1
Tertiary	['SI']	1
Agriculture/ Forestry	['SI']	1
Other energy consumption	['SI']	1
Municipal solid waste (MSW) generation	['SI']	1
Municipal solid waste (MSW) going to landfills	['SI']	1

A3.4 Activity drivers' connection to IPCC sectors

Table 33 Number of activity drivers corresponding to IPCC sectors, as well as activity drivers with no connection to any sector.

Sectoral projections	Parameter	Count
Unknown sector	['Gross value added (GVA) - agriculture', 'Number of appartments', 'Household size', 'Gross floor area - other buildings', 'Number of passenger-kilometres', 'Final non-energy consumption', 'Passenger cars', 'Public transport - busses', 'Food & beverage industry', 'Full-time equivalent (all sectors)', 'Chlorine production', 'Freight transport - light trucks', 'Gross floor area - office buildings', 'Indigenous Production by fuel type', 'Number of cooling degree days (CDD)', 'Gross floor area - hospitals', 'Gross value added', 'Deforested land', 'Net imports Electricity', 'Ethyleen production', 'rabbit population', 'Heat generation from thermal power generation', 'Heat generation from combined heat and power plants, including industrial waste heat', 'Exchange rates EURO', 'Industrial waste deposited, biodegradable origin', 'Livestock', 'Gross value added (GVA) - industry', 'Afforested land', 'Final energy consumption - Other', 'Population', 'Freight transport tonnes-kilometres', 'Agriculture', 'Primary aluminum production', 'Final energy consumption - Transport', 'Ceramic production', 'Industry', 'Municipal solid waste (MSW)', 'Households', 'Number of households', 'International shipping (bunker fuels)', 'Freight transport - heavy trucks', 'Basic metal - non ferro', 'Harvested wood products', 'Number of other houses', 'Freight transport (road) and buses', 'Gross value added (GVA) - services', 'Passenger road transport', 'Gross floor area - commercial buildings', 'Ammonia production', 'Share of CH4 recovery in total CH4 generation from landfills', 'Nitrogen in crop residues returned to soils', 'Electricity prices by type of using sector', 'Basic metal - ferro', 'Exchange rates US DOLLAR', 'Methanol production', 'Gross value added (GVA)- construction', 'Gross value added (GVA) - energy sector', 'Final energy consumption - Industry', 'Area of cultivated organic soils', 'Transport', 'EU ETS carbon price', 'Nitrogen input from application of manure', 'Gross inland consumption by fuel type source', 'goat population', 'Final energy consumption - All sectors', 'Waste processing industry', 'Gross value added (GVA)- total', 'Exchange rates US DOLLAR, if applicable', 'Waste inceneration', 'Glass production', 'Other energy consumption', 'Nitrogen input from application of synthetic fertilizers', 'Chemical industry', 'Managed wetland', 'Service sector', 'Fuel inputs to thermal power generation', 'Managed grassland', 'Gross electricity generation', 'International (wholesale) fuel import prices', 'Managed cropland', 'Exchange rates EURO (for non- EURO countries), if applicable', 'Other industry', 'National retail fuel prices', 'Gross domestic product', 'Fuel inputs to other conversion processes', 'Industrial waste generation, biodegradable origin', 'Number of terraced houses', 'International aviation (bunker fuels)', 'Gross floor area - education', 'Electricity prices', 'Remaining fuel demand transport', 'Number of heating degree days (HDD)', 'Data Centre Median Demand installed capacity', 'Steel production', 'Disposable income of households', 'Energy reference area (total)', 'Managed forest land', 'Service sector (including data centres)', 'Nitrogen fixed by N- fixing crops', 'Fertilizer industry', 'Final energy consumption - Tertiary', 'Final energy consumption - Residential', 'Salt production', 'horse population', 'Final energy consumption - Agriculture and Forestry', 'Average day temperature']	106

Sectoral projections	Parameter	Count
International Aviation in the EU ETS 1.A.3.a Domestic aviation	['Freight transport tonnes-kilometres', 'Number of Landing and Take-Off cycle - international aviation', 'Final energy consumption - Transport', 'Number of passenger-kilometres']	4
5 Waste	['Population', 'Municipal solid waste (MSW)', 'Share of CH4 recovery in total CH4 generation from landfills', 'Methane recovery', 'Municipal solid waste (MSW) generation', 'Municipal solid waste (MSW) going to landfills']	6
4 LULUCF	['Cropland converted to grassland, organic soils', 'Cropland converted to other land', 'Grassland converted to other land', 'Cropland converted to grassland, mineral soils', 'Index of produced semi-chemical wood pulp volume to industrial roundwood production', 'Grassland remaining grassland, share of drained areas from organic soils', 'Grassland converted to cropland, organic soils', 'Forest land remaining forest land, share of drained areas from organic soils', 'Forest available for wood supply with additional protective measures (excluding water protection forests on banks)', 'Forest land converted to grassland, organic soils', 'Cropland converted to settlements, organic soils', 'Forest land remaining forest land, organic soils', 'Afforested land', 'Shrubland fires', 'Grassland converted to cropland, mineral soils', 'Grassland converted to settlements, organic soils', 'Cropland remaining cropland, average SOC stock', 'Production of horticultural peat', 'Wetlands converted to grassland', 'Grassland converted to forest land, organic soils', 'Wetlands converted to forest land, organic soils', 'Managed forest land', 'Forest not available for wood supply', 'Index of produced paper and paperboard volume to industrial roundwood production', 'Coniferous forests fires', 'Index of produced wood-based panels volume to industrial roundwood production', 'Cropland, remaining cropland, organic soils', 'Grassland remaining grassland, organic soils', 'Herbaceous grassland fires', 'Total felling volume', 'Managed wetland', 'Grassland converted to wetlands', 'Grassland converted to settlements, mineral soils', 'Area of rewetted peat extraction sites', 'Index of produced sawnwood volume to industrial roundwood production', 'Managed grassland', 'Other land converted to grassland', 'Harvested wood products', 'Deforested land', 'Forest land converted to settlements, organic soils', 'Broadleaf forest fires', 'Managed cropland', 'Settlements converted to forest land, organic soils', 'Area of active peat extraction sites', 'Settlements converted to grassland', 'Cropland converted to settlements, mineral soils']	46
3 Agriculture	['Urea in milk', "The share of ring storage tanks with natural crust from cattle's liquid manure storages", 'Afforested land', 'Nitrogen input from application of manure', "The share of lagoons with floating cover from swine's liquid manure storages", 'Livestock', 'Gross value added', 'The share of closed storage tanks from swine liquid manure storages', 'Nitrogen in crop residues returned to soils', 'Nitrogen fixed by N- fixing crops', 'Area of cultivated organic soils', "The share of lagoons with natural crust from cattle's liquid manure storages", "The share of closed storage tants from cattle's liquid manure storages", "The share of ring storage tanks with floating cover from swine's liquid manure storages", 'Final energy consumption - Agriculture and Forestry', 'Milk yield', 'Nitrogen input from application of synthetic fertilizers']	17
2 Industrial Processes and product use	['Disposable income', 'Final non-energy consumption', 'Gross value added', 'Gross domestic product']	4
1.B Fugitive emissions from fuels	['Indigenous Production by fuel type']	1
1.A.4.b Residential	['Disposable income of households', 'Population', 'Residential', 'Number of households', 'Household size', 'National retail fuel prices', 'Final energy consumption - Tertiary', 'Final energy consumption - Residential', 'Electricity prices']	9
1.A.4.a Commercial/institutional	['Agriculture/ Forestry', 'Final energy consumption - Transport', 'Final energy consumption - Agriculture and Forestry', 'Gross value added', 'Number of households', 'Transport', 'Household size', 'Final energy consumption - Tertiary', 'Tertiary', 'Electricity prices']	10
1.A.3 Transport excluding 1.A.3.a domestic aviation	['Number of heavy duty vehicles', 'Number of passenger- kilometres - road', 'Number of vehicles - Hydrogen', 'Freight transport tonnes - kilometres - domestic aviation', 'Number of passenger- kilometres - domestic aviation', 'Freight transport tonnes - kilometres - domestic navigation (inland waterways and national maritime)', 'Freight transport tonnes-kilometres', 'Number of passenger- kilometres (all modes)', 'Number of passenger-kilometres', 'Number of vehicles - CNG (bio)', 'Number of vehicles - Diesel', 'Transport', 'Number of light commercial vehicles', 'Final energy consumption - Transport', 'Number of passenger-kilometres - domestic navigation', 'Number of electricity-powered light commercial vehicles', 'Gross inland consumption by fuel type source', 'Number of electricity-powered heavy duty vehicles', 'Freight transport tonnes - kilometres - international aviation', 'Final energy	33

Sectoral projections	Parameter	Count
	consumption - All sectors', 'Freight transport tonnes - kilometres (all modes)', 'National retail fuel prices', 'Number of passenger cars', 'Number of passenger- kilometres - international aviation', 'Number of Landing and Take-Off cycle - domestic aviation', 'Freight transport tonnes - kilometres - rail', 'Number of electricity-powered passenger cars', 'Number of passenger- kilometres - rail', 'Freight transport tonnes - kilometres - road', 'Number of vehicles - Electric', 'Gross value added', 'Number of hydrogen-powered vehicles', 'Number of vehicles - Gasoline']	
1.A.2 Manufacturing industries and construction	['Gross inland consumption by fuel type source', 'Freight transport tonnes-kilometres', 'Industry energy consumption', 'Industry', 'Final energy consumption - All sectors', 'Number of passenger-kilometres', 'Final energy consumption - Industry', 'Fish caught', 'National retail fuel prices', 'Indigenous Production by fuel type', 'Electricity prices']	11
1.A.1 Energy industries	['EU ETS carbon price', 'Enefit280 oil shale plants', 'Gross inland consumption by fuel type source', 'Fuel inputs to thermal power generation', 'Fuel inputs to other conversion processes', 'Gross electricity generation', 'Final energy consumption - All sectors', 'Gross value added', 'Municipal solid waste (MSW)', 'Net imports Electricity', 'International (wholesale) fuel import prices', 'Petroter oil shale plants', 'Share of CH4 recovery in total CH4 generation from landfills', 'Heat generation from thermal power generation', 'Heat generation from combined heat and power plants, including industrial waste heat', 'Final energy consumption - Agriculture and Forestry', 'Indigenous Production by fuel type']	17

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