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Nowcasting and outlooks of EEA circular economy indicators

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Summary / Description

The European Environment Agency (EEA) uses six indicators to track progress of the circular economy agenda in Europe and in individual countries. These indicators include: (1) the EEA consumption footprint of Europe, (2) Europe's material footprint, (3) the circular material use rate (CMUR) in Europe, (4) Waste recycling in Europe, (5) Waste generation and decoupling in Europe, and (6) Diversion of waste from landfills in Europe. These indicators are relevant for a variety of EEA activities such as the newly launched Circularity Metrics Lab (CML), the State and Outlook of the Environment Report (SOER), the Zero Pollution Monitoring Framework, or the monitoring of the 8th Environmental Action Programme (EAP).

Furthermore, for some of these indicators specific policy objectives have been defined (e.g., to double the CMUR by around 2030, to significantly reduce Europe's consumption and material footprints, or the definition of specific waste targets) and progress towards these objectives has to be continuously tracked. Such monitoring efforts should be based on recent and up-to-date data, which can be challenging as the underlying statistics are only being published with some time delay, e.g., due to data collection and statistical procedures currently in place. Furthermore, outlooks highlighting possible future developments of the indicators against the background of forecasted population and economic trends and the influence of policies are not yet regularly provided by EU institutions.

Against this background, this report is twofold: Firstly, we explore and implement possible methodological approaches for **nowcasting** each of the six EEA indicators at EU-27 and member state level to the most recent year possible (*carried out by ISRPA, VITO, and UBA*). Secondly, **outlooks** for each of the six indicators up to the year 2035 are implemented using an autoregressive analysis approach (*carried out by SEEDS*).

For this, we firstly screen available data and methods and highlight pros and cons of these for use by the EEA, also considering their scientific robustness and availability for future implementation in-house the agency. The proposed nowcasting approaches use different methods depending on the type of the indicator including, e.g., the use of annual relative changes in the predictors, annual average growth rates, and regression models (e.g., regression of absolute values, regression of absolute changes, regression of relative changes, regression of logged values). Outlooks are based on the use of statistical and econometric methodologies using time series of historical data to generate ex-ante and ex-post outlooks for the medium-term (2022-2035).

1 Introduction

1.1 Policy background

The indicators by the European Environment Agency (EEA) aim at capturing and informing the various phases of environmental policy making, i.e., from agenda setting to policy formulation to adoption, implementation, evaluation/monitoring, and maintenance (EEA, 2023; Jann and Wegrich, 2007). Indicators highlight the status of a specific phenomenon under investigation, often using time series data and information. If a policy objective or quantitative target is available, the EEA indicators website discusses the distance to this target and possible reasons for this. The EEA indicators currently consist of 14 clusters[1] covering a wide range of environmental topics. Among them, the cluster *'Resource efficiency and waste'* currently consists of the six indicators: (1) material footprint, (2) EEA consumption footprint, (3) waste generation, (4) waste landfill diversion, (5) waste recycling, and (6) circular materials use rate (CMUR) which are the focus of this report. All of these indicators are reported in time-series data for the EU-27 and at the level of individual EU member countries, and in some cases also other EEA member countries.

Besides being standalone products, these six indicators are relevant to a variety of EEA activities such as the newly launched Circularity Metrics Lab (CML)[2], the State and Outlook of the Environment Report (SOER)[3], the Zero Pollution Monitoring Framework (EC, 2021), or the monitoring of the 8th Environmental Action Programme (EAP) (EC, 2022). Furthermore, for some of these indicators specific policy objectives have been defined, e.g., to double the CMUR in the coming decade (EC, 2020), to significantly reduce Europe's consumption footprint (European Green Deal (EGD) (EC, 2019)), or the definition of specific waste targets (EC, 2018)), making it necessary to also track progress towards these targets using recent data to inform policy making.

The following paragraphs briefly describe each of the six indicators:

1. Europe's material footprint *(footprint indicator)*

The material footprint captures the amount of raw materials extracted from nature, both inside and outside the EU, to manufacture or provide the goods and services consumed by EU citizens. It refers to *raw materials consumption (RMC)* and is based on economy-wide material flow accounts (EW-MFA) and captures trade in raw material equivalents (RME)[4]. The EGD (EC, 2019) calls for a decoupling of economic growth from resource extraction and the 8th EAP (EC, 2022) aims at significantly decreasing the EU's material footprint.

2. EEA Europe's consumption footprint *(footprint indicator)*

The EEA consumption footprint highlights the life-cycle environmental impacts resulting from the consumption of goods and services by EU-27 final demand also considering impacts of trade. It can help to inform about the extent by which environmental impacts are outsourced and allows for comparisons with environmental thresholds such as the planetary boundaries (Sala et al., 2020; Rockström et al., 2009; Steffen et al., 2015). The indicator is based on the multi-regional input-output (MRIO) database EXIOBASE including environmental extensions (Wood et al., 2015). As such, it differs methodologically from the life-cycle assessment (LCA)-based consumption footprint indicator put forth by the European Commission (Sanye Mengual and Sala, 2023) and can provide complementary information for resources

[1] Agriculture, air pollution, biodiversity – ecosystems, climate change adaptation, climate change mitigation, energy, environment and health, industry, land use, resource efficiency and waste, soil, sustainability transitions, transport, water and marine environment.

[2] https://circularity.eea.europa.eu/

[3] https://www.eea.europa.eu/soer/2020

[4] https://ec.europa.eu/eurostat/databrowser/view/env_ac_rme/default/table?lang=en

monitoring. The 8th EAP includes the aim to significantly reduce the EU's consumption footprint (EC, 2022).

3. Waste generation in Europe *(waste indicator)*

The indicator tracks the amount of waste generated by member states. It is based on the EU Waste Framework Directive (EC, 2018) which, with its waste hierarchy, aims at reducing waste by preventing waste generation (highest priority to waste prevention, followed by preparing for reuse, recycling, and other methods of recovery and disposal). The information on waste generation provides a breakdown by economic activity according to the NACE[5] classification plus households, and by waste category according to the European Waste Classification for statistical purposes[6]. It is a headline indicator for monitoring progress towards the 8th EAP (EC, 2022) and informs the zero pollution ambition (EC, 2021) calling for a significant reduction in EU waste generation by 2030.

4. Diversion of waste from landfill in Europe *(waste indicator)*

Sending waste to landfills is the least desirable option according to the waste hierarchy (EC, 2018). This indicator uses Eurostat data on waste generation and treatment to track the amounts and share of waste deposited in landfills, by type of waste category.

5. Waste recycling in Europe *(waste indicator)*

The recycling rate captures the proportion of waste generated that is recycled for different waste streams such as packaging waste, electrical and electronic waste (WEEE), municipal waste, and overall waste amounts (total waste generated excluding major mineral wastes). Policy targets stem, e.g., from the WEEE Directive (EU, 2012) for the separate collection and recycling of electrical and electronic waste, the Waste Framework Directive (EC, 2018) for the recycling and preparation for reuse of municipal waste, or the Packaging and Packaging Waste Directive (EU, 2018) for recycling packaging waste. Overall, more than 30 binding targets are included in EU waste legislation for the time period 2015-2030[7]. It is based on Eurostat waste statistics.

6. Circular material use rate (CMUR) in Europe *(material flow and waste statistics)*

The CMUR captures the level of circularity of an economy and refers to the share of materials used which stem from recycled waste materials. The EU CE action plan calls for a doubling of the CMUR in the coming decade (approximately between 2020 and 2030, although no specific date is mentioned). Data come from Eurostat[8]

1.2 Indicator update frequency

The above policy outputs and targets/objectives should be based on recent and up-to-date data, which can be challenging as the underlying statistics are only being published with some time delay, e.g., due to data collection and statistical procedures currently in place. Furthermore, outlooks highlighting possible developments of the indicators into the future are not yet regularly provided by EU institutions.

The six indicators discussed within this report are regularly updated by Eurostat (material footprint, waste and recycling indicators, CMUR) or the EEA (EEA consumption footprint). However, due to data collection and statistical/analytical procedures in place, time delays in updating each of the indicators of roughly 2-3 years exist (Table 1.1).

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5 Statistical classification of economic activities in the European Community (NACE) (French: **N**omenclature statistique des **a**ctivités économiques dans la **C**ommunauté **e**uropéenne)

6 https://ec.europa.eu/eurostat/web/waste/data/database

7 Source: https://www.eea.europa.eu/ims/waste-recycling-in-europe

8 Source: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Circular_economy_-_material_flows

Table 1.1 Current data availability by indicator (at the time of writing) and regular update time frames

Indicator	Compiling agency	Current time series[9]	Next update
Europe's material footprint	Eurostat	2000-2020 (MS-level from 2008 onwards)	**T+2 years**: EU RME model calculations are usually undertaken in August. Results are usually published in September, 21 months after the end of the last reference year. Country level estimates are published in November after validation of the data collected via the EW-MFA questionnaire and Eurostat estimates at country level have been updated.
Europe's consumption footprint	EEA	2010-2021	Update by ETC-CE with deadline **30 June 2023** (2021-data)
Waste generation and decoupling in Europe	Eurostat	2010-2020	[env_wasgen]: 2004-2020, **even years**, T+20 months
Diversion of waste from landfill in Europe	Eurostat	2010-2020	[env_wasmun]: 1995-2021, T+12 months [env_wastrt]: 2014-2020, **even years**, T+20 months
Waste recycling in Europe	Eurostat	2004-2020	Frequency of data publishing is **every 2 years** (for waste generation) to every year (for population and GDP). [env_wasmun]: 1995-2021, T+12 months [env_waspac]: 1997-2020, T+22 months [env_wasgen]: 2004-2020, even years, T+20 months [env_wasoper]: 2010-2020, even years, T+20 months [cei_wm050]: 2008-2018, T+2 years
Circular material use rate in Europe	Eurostat	2004-2021 (MS-level from 2010 onwards)	**November 2023**: 2022-estimate

Note: T: Time

In the coming decades, growing populations with higher incomes will drive a strong increase in global demand for goods and services, and, as a result, for the material resources to support this growth. Moreover, demographic (i.e., ageing) and technological (e.g., automation) changes will also greatly impact the environmental consequences of production and consumption (EEA, 2019). At the same time, technological developments (e.g., materials efficiency improvements, material substitution, etc.) and policy-induced changes (e.g., climate and circular economy policies) will significantly alter the socio-economic metabolism including natural resource uses and waste/emissions generated. Additional *outlook analysis* is, thus, essential in identifying long-term risks, trends, and issues that may require policy action and exploring strategic options. It can also inform policy design and implementation and can be used to engage citizens and stakeholders in thinking about the future[10].

1.3 Goal and scope of this report

Against this background, the **overarching goals** of this report are to:

9 At the time of writing.

10 Nowcasting focuses on providing real-time or near-term predictions based on current data, whereas outlooks encompass broader perspectives on future possibilities based on existing information and trends. Foresight involves a proactive approach to anticipate and understand long-term developments, often employing various methodologies and analysis of emerging trends. Scenarios explore plausible alternative future narratives to capture uncertainties and implications, while predictions are specific statements or forecasts about future events or conditions based on available information and models.

1. Provide an overview of available **nowcasting methods** for each of the six indicators, make recommendations for the methods to be applied at EU-27 and country level, and implement the methods using simple excel tools for use by the EEA.
2. Develop and implement an **outlook methodology** to highlight the likely evolution of the six EEA indicators up to the year 2035 and implement this method using a simple excel tool for use by the EEA.

1.3.1 Nowcasting

Specific goals of the nowcasting task include:

- Develop methodologies, based on accepted scientific validity, suitable for filling data gaps in the indicators' datasets as well as to perform short projections, estimating data for the latest possible year.
- Provide a short description of the methodology, including practical guidance for how to apply it to the six EEA CE indicators.
- Discuss the proposed approach with relevant stakeholders (e.g., Eurostat) and apply it to the six indicators.
- Provide the EEA with a tool (Excel-based) to continue this work stream in house whenever new data become available.

The Eurostat publication timeline determines the latest possible year that can be nowcasted using some of the methods proposed within this working paper. If nowcasts for the previous and current year cannot be provided using the nowcasting methods, estimates for these might be included within the results of the outlooks.

1.3.2 Outlooks

The goal of the outlook exercise is to provide a transparent, robust but tractable tool to be used by EEA experts to update regularly the outlook once the selected indicators are updated. The outlook should consider the evolution of past trends, the role played by the main drivers and their projected future trends, and the role played by legislative initiatives relevant, e.g., to the circular economy action plan and the EU waste legislation.

The outcome will not develop scenarios, but instead will inform the EEA about the most likely development of the indicators given up-to-date available information and simple modelling assumptions.

2 Nowcasting approaches for the six EEA indicators

2.1 State of knowledge on nowcasts

The term *"nowcasting"* is a combination of *"now"* and *"forecasting"* and was first used in meteorology to provide short-term weather predictions on timescales of a few hours (Wapler et al., 2019). In the area of policy and economics, Banbura and colleagues define nowcasting as *"the prediction of the present, the very near future and the very recent past"* (Banbura et al., 2010). Nowcasting conducted in policy institutions can be based on various approaches such as, e.g., expert judgements, simple models, regression analysis based on multiple predictors, or advanced modeling (e.g., using alternative and almost real-time data)[11].

In the context of material flow accounts, a number of nowcasting activities are reported in the literature making use of adaptations of the Eurostat RME model (ECORYS, 2013), regression modeling using a range of predictor variables (UBA, 2019; Eurostat E2, 2021), and simple adjustments based on historical trade relationships (UBA, 2022, 2023). With regard to the EEA consumption footprint, latest data for the EXIOBASE 3 MRIO time-series of monetary tables rely on nowcasting economic structure (and environmental extensions) to more recent years (up to 2022) (Stadler et al., 2021). The time-series is based on the nowcasting procedures and projections of GDP and aggregate trade of the International Monetary Fund[12]. With regard to economy-wide material flow accounts, Eurostat annually produces the early estimates at T+6 months for domestic extraction at the level of the four main material categories (de la Fuente and Marra Campanale, 2016).

The following chapters will discuss possible nowcasting approaches for each of the six indicators in more depth and highlight their advantages and disadvantages. Note that the data available at the time of writing (around mid-2023) are given in this chapter.

2.2 Material footprint

Calculations by Eurostat of the material footprint are based on the RME-model which converts product flows into raw material equivalents (RME) using Leontief input-output (IO) analysis (Miller and Blair, 2009). At the center of the RME model is a hybrid IO table for the EU-27 with 182x182 product group resolution termed the ADTA-IO (adapted domestic technology assumption input output) model (Eurostat, 2022a). It is developed by fitting more detailed structural information to the FIGARO IOT[13] which is currently (at the time of writing) available for the period 2010 to 2020. In the RME model, different adjustments are made to improve RME estimates for imports, for example, by considering regionalized information on metal recycling ratios, metal content of imports (e.g., based on life-cycle inventory data), or regional energy mixes. Eurostat also provides a country RME-tool in which estimates of RME of imports are based on EU-level import- and export-coefficients combined with hybrid country-level trade vectors (Eurostat, 2023b).

The material footprint is calculated as follows:

$$\textbf{Material footprint: RMC = DE + IMP}_{\textbf{RME}} \textbf{ – EXP}_{\textbf{RME}}$$

where RMC = Raw Materials Consumption, DE = Domestic extraction, IMP = Imports, EXP = Exports, and RME = Raw Material Equivalents.

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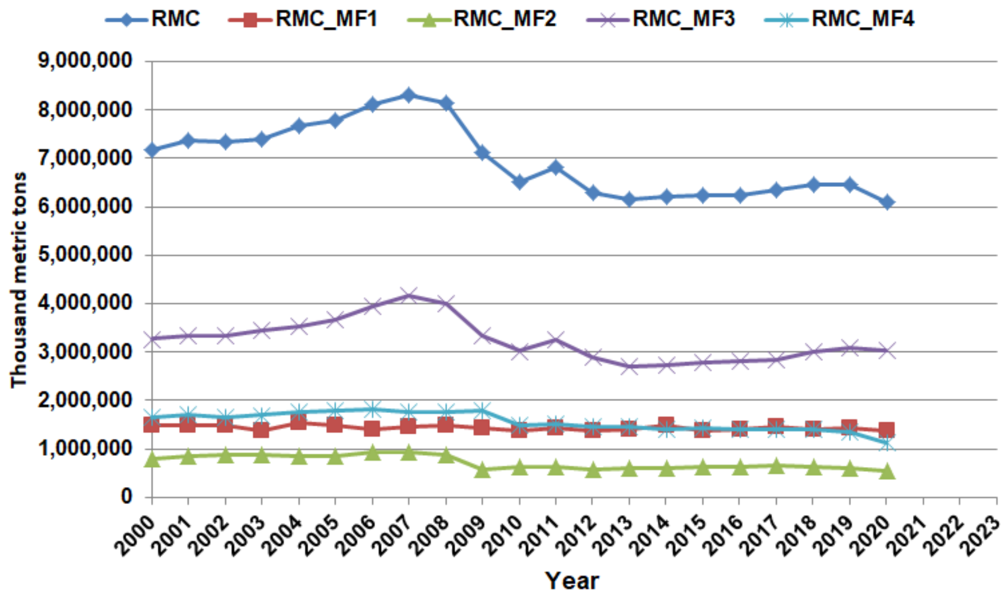
11 For example, see the European Statistics Awards for Nowcasting (https://statistics-awards.eu/).

12 https://konstantinstadler.site/posts/exiobase-update-v38/

13 https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/data/database

Eurostat's dataset ENV_AC_RME provides data for the EU-27 from 2000 until 2020 for the material footprint (raw material consumption RMC) including its four material categories (Figure 2.1).

Figure 2.1 Raw material consumption (material footprint) and the underlying material categories from 2000 to 2020 for the EU-27 using Eurostat data (available data at the time of writing).



Note: MF1: biomass, MF2: metal ores, MF3: non-metallic minerals, MF4: fossil energy materials/carriers
Source: Eurostat ENV_AC_RME

2.2.1 Characteristics of the Eurostat database

Data timeliness:
According to the Commission Delegated Regulation 2022/125, starting from 2023 the EW-MFA data collection has a new production cycle[14]. Data for *domestic extraction* and direct physical imports (in net weight and not in RME) and exports in EW-MFA accounts are collected by Eurostat via a questionnaire from national statistical institutes (NSI) by 30 April and refer to data reported for reference year T-2 year. Along with the release of the results of the questionnaire (three months after the reporting deadline of 30 April), Eurostat publishes the early estimates for the previous year (T-1y) for the four main material categories. Early estimates for domestic extraction, import and exports are produced for each EU Member State and aggregated at the EU level. Domestic extraction estimates are based on regression-type models which use predictors such as production volume indices from short-term business statistics. Predictors and prediction models are country and material flow category specific (i.e., different predictors for domestic extraction by material category can be applied for different EU counties). Imports and exports are based on actual quantities reported by international trade in goods statistics[15].

Eurostat *RME model calculations* (imports and exports in RME) for the EU-27 are usually undertaken in August with results published in September for the EU-27, i.e., around 21 months after the end of the last reference year (t + 21 months)[16]. Estimates for individual countries are published in November after

[14] Eurostat (2022): *Physical environmental accounts: data collections 2021 and plans for 2022*. Document (ENV/EA-MESA/WG /2022/21) of the Joint meeting of the Working group environmental accounts & Working group monetary environmental statistics and accounts, 3-5 May 2022

[15] https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_mfa_sims.htm

[16] https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_mfa_sims.htm

the data collected via the EW-MFA questionnaire have been validated and the country-level estimates by Eurostat have been updated. Data at the time of writing (March 2023) are available up to 2020 and data for 2021 should become available around September (EU-27) and November 2023 (EU-MS), respectively.

Coverage by material type:
The EW-MFA data distinguish between main categories of materials which each can be broken down into further subcategories:

- Total (sum of the below)
- Biomass (classification code MF1)
- Metal ores (gross ores) (MF2)
- Non-metallic minerals (MF3)
- Fossil energy materials/carriers (MF4)

Geographical coverage:
Data on domestic extraction is available for the EU-27, individual member states (MS), the UK and EFTA[17] countries, and EU candidate countries. EW-MFA data in RME are available for the EU-27, individual MS, and Switzerland.

Data gaps:
Data gaps exist as follows:

- Imports and exports in RME at MS level are missing for several countries (i.e., no data are available for Bulgaria, Czechia, Ireland, Greece, Spain, Croatia, Cyprus, Latvia, Hungary, Poland, Slovenia, Slovakia, Finland, and Sweden).
- RME import/export estimates for 2020 are only available for the EU-27, Italy, and Luxembourg.
- With the exception of the EU-27, no data for raw material subcategories are provided for RME estimates.

2.2.2 Nowcasting methodologies

Several studies could be identified that carried out nowcasting exercises for the material footprint. Note that this list simply aims at providing a first overview of differing approaches and might not be complete. The studies and their approaches are summarized as follows:

- **Use of predictors and RME coefficients**

A study by ECORYS and the Copenhagen Resource Institute was carried out for the European Commission DG Environment to assess possibilities for developing early estimates and nowcasts of various resource efficiency indicators (ECORYS, 2013).

For *domestic extraction*, the study identified production indicators relevant for predicting production of the most relevant material categories (measured in terms of their contribution to material flows), i.e., non-metallic minerals (mostly building materials), oil & gas and coal, crops and crop residues, metal ores, and wood. Predictors used for domestic extraction are highlighted in Table 2.1.

[17] European Free Trade Association (EFTA) countries: Iceland, Liechtenstein, Norway and Switzerland

Table 2.1 Predictors for domestic extraction in the approach

MFA identifier	Name	Predictor	Reference	Timeliness
MF11-12	Crops and crop residues	Eurostat Agricultural Production Data (Harvested production:1000s tonnes)	Crops Production Database (apro_cpp_crop), Fruits and Vegetables Database (apro_cpp_fruveg	T+4 months (April)
MF13	Wood	Forestry production data	Eurostat database: for_remov. All species of tree, roundwood, under bark, thousands of cubic metres.	T+11 months (November)
MF21-22	Metal ores	Production volume ('000 tonnes) for selected detailed product codes related to basic metals industries	PRODCOM Codes: 07101000, 07291100, 07291200, 07291300, 07291400, 07291500, 07291900.	T+7 months (July)
MF3	Non-metallic minerals	Production volume ('000 tonnes) for selected detailed product codes related to construction	PRODCOM Codes: 08111133, 08111136, 08121250, 08111233, 08111236, 08111290, 08121290, 08113010, 08911100, 08113030, 08114000, 08931000, 08112050, 08112030, 08121190, 08122140, 08122160, 08122210, 08122230, 08122250, 08121210. 08121230.	T+7 months (July)
MF41	Coal and other solid energy materials / carriers	Eurostat Energy Statistics – Solid Fuels	Eurostat database: nrg_101a. Primary production of all solid fuels (product code: 2000) in 1000s tonnes.	T+11 months (November)
MF42	Liquid and gaseous energy materials / carriers	Eurostat Energy Statistics – Liquid and Gaseous Fuels ('000 tonnes).	Eurostat Energy databases, (nrg_102a, nrg_103a). Primary production (B_100100) of total petroleum products (3000) and total gas (4000). Gas converted from TJ (GCV) to 1000 tonnes using conversion factor = 1/50.	T+11 months(November)

Source: (ECORYS, 2013)

For each member state and material, a simple equation using ordinary least squares estimation was used to predict domestic extraction (and other EW-MFA indicators including DMC) using the predictors as the explanatory variable. The goodness of fit (R^2) indicates the extent to which the resulting equation predicts the actual domestic extraction values. The results highlighted that the production statistics provided reasonable predictors. However, challenges were identified, e.g., with regard to nowcasting domestic extraction of MF12 (crops) and metal MF2 metal ores as well as for some EU countries.

For imports and exports, nowcasts are provided by using Comext trade data which are available at T+2 months. Trade data by weight for the relevant codes of the Combined Nomenclature (CN) were aggregated into the respective MFA categories following the guidance of the Eurostat EW-MFA Questionnaire. The process to predict RME figures for import and exports relied on the use of historical hybrid input-output tables (IOTs) to derive RME coefficients along the lines of the Eurostat RME model (see details in the ECORYS report). Overall, this method is time intensive.

- **Regression models**

The UNEP International Resource Panel (IRP) carried out an analysis of the drivers of changes in the material footprint over time using the IPAT equation (I = P x A x T) which conceptualizes environmental impacts (I) as the product of population (P), affluence (A), and a technological coefficient (T) (UNEP, 2016). In their study, the parameters of the IPAT-equation are defined as follows: I as materials use (either DMC or RMC), A as GDP per capita (USD at 2005 constant prices), and T as material intensity (i.e., DMC/GDP or RMC/GDP). Relative contributions were then assessed by transforming the IPAT equation to a logarithmic form using a predefined approach from the literature (STIRPAT, (York et al., 2003)). Results highlight that population and affluence can be seen as important drivers of natural resource use in various world regions. In Europe, improvements in the technological coefficient combined with a rather steady population figure have been able to lower overall RMC. Population and GDP, therefore, also seem relevant predictors for nowcasting RMC or providing outlooks.

A study by Lutz and colleagues (UBA, 2019) examined a wide range of environmental indicators using German statistics and discussed options to nowcast these to the current year. For the material footprint, the research team concluded that the developments are relatively stable in the long-term and are influenced in the short term by economic factors such as the 2008/09 economic downturn. Nowcasts were then provided using regression analysis with a range of predictors including population data, the ratio of price-adjusted gross capital formation to price-adjusted domestic aggregate demand, and the ratio of price-adjusted German imports to price-adjusted German exports. Using the historical RMC data from 2000 to 2014 and data until 2017 for the predictor variables, a nowcasting for RMC per capita for the years 2015, 2016, and 2017 was then carried out.

- **Annual change rate of direct import and exports**

A study by Lutter and colleagues (UBA, 2022) (detailed methods report available at (UBA, 2023)) aims at nowcasting the material footprint for Germany up to 2020 in the context of the UBA DeuRess project published in 2022. The year 2020, however, was unique due to the global COVID pandemic and associated lockdowns which led to significant changes in production and consumption patterns. Available methods to nowcast material footprint data via regression analysis were, therefore, only partially applicable.

The UBA study therefore uses the following approach to nowcast RMC for 2020 for Germany:

a) Early estimates for domestic extraction were available for the year 2020 from Eurostat EW-MFA statistics. Furthermore, data on direct physical imports and exports in net weight (not in RME) by material group were available from the same source.
b) The percentage change between 2019 and 2020 by material group and trade flow were applied to the RME of import and exports, respectively. This approach follows the observation that changes in direct imports and exports (net weight) are often similar to the changes in indirect imports and exports (in RME).
c) The material footprint (RMC) was then estimated using the officially reported data for domestic extraction and the estimated data for indirect imports and exports to nowcast the indicator by one year (up to 2020 while reported Eurostat estimates were only available up to 2019 at the time of writing the UBA report).

<u>Application to EU-27 data:</u>

For the EU-27, a comparison of the ratios IMP/IMP_{RME} and EXP/EXP_{RME} from 2000 to 2020 highlights a data break in 2010 (Table 2.2).

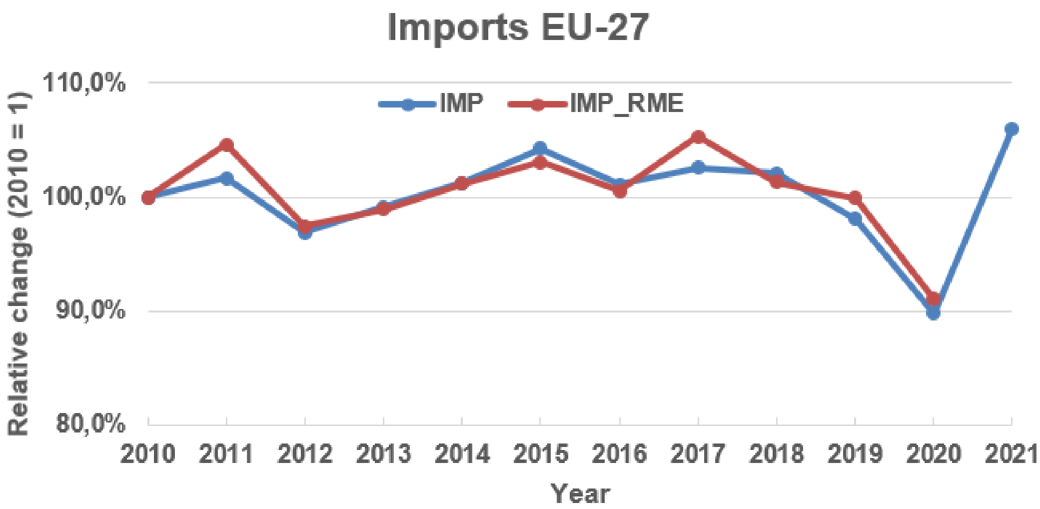
Table 2.2. Ratios of IMP/IMP_{RME} and EXP/EXP_{RME} from 2000 until 2020 based on Eurostat data

Ratio	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
IMP/IMP_RME	0,42	0,39	0,41	0,43	0,44	0,44	0,42	0,41	0,40	0,39	0,53	0,51	0,51	0,51	0,51	0,52	0,52	0,51	0,51	0,50	0,49
IMP_MF1/IMP_RE_MF1	0,53	0,54	0,58	0,61	0,64	0,65	0,64	0,60	0,59	0,64	0,88	0,83	0,79	0,82	0,84	0,87	0,84	0,83	0,83	0,81	0,80
IMP_MF2/IMP_RME_MF2	0,21	0,19	0,19	0,20	0,22	0,23	0,21	0,21	0,20	0,18	0,23	0,24	0,23	0,24	0,24	0,25	0,24	0,24	0,25	0,25	0,23
IMP_MF3/IMP_RME_MF3	0,16	0,16	0,16	0,17	0,19	0,19	0,17	0,18	0,16	0,13	0,27	0,23	0,21	0,23	0,24	0,23	0,24	0,20	0,22	0,20	0,22
IMP_MF4/IMP_RME_MF4	0,61	0,57	0,62	0,63	0,62	0,61	0,60	0,60	0,59	0,52	0,71	0,70	0,69	0,66	0,66	0,66	0,67	0,68	0,67	0,65	0,66
EXP/EXP_RME	0,23	0,22	0,24	0,25	0,25	0,26	0,26	0,24	0,24	0,25	0,33	0,31	0,33	0,35	0,35	0,34	0,36	0,33	0,33	0,32	0,32
EXP_MF1/EXP_RME_MF1	0,45	0,47	0,49	0,53	0,54	0,58	0,61	0,51	0,51	0,56	0,70	0,63	0,65	0,67	0,65	0,70	0,69	0,66	0,66	0,67	0,64
EXP_MF2/EXP_RME_MF2	0,17	0,17	0,19	0,20	0,20	0,21	0,19	0,18	0,17	0,21	0,23	0,24	0,26	0,24	0,23	0,22	0,22	0,23	0,20	0,22	0,20
EXP_MF3/EXP_RME_MF3	0,16	0,15	0,15	0,16	0,16	0,17	0,15	0,13	0,13	0,12	0,19	0,17	0,20	0,23	0,25	0,23	0,24	0,17	0,18	0,15	0,15
EXP_MF4/EXP_RME_MF4	0,17	0,17	0,18	0,18	0,20	0,21	0,22	0,23	0,22	0,21	0,29	0,28	0,29	0,31	0,30	0,29	0,32	0,34	0,33	0,32	0,34

Source: Eurostat data (ENV_AC_MFA and ENV_AC_RME)

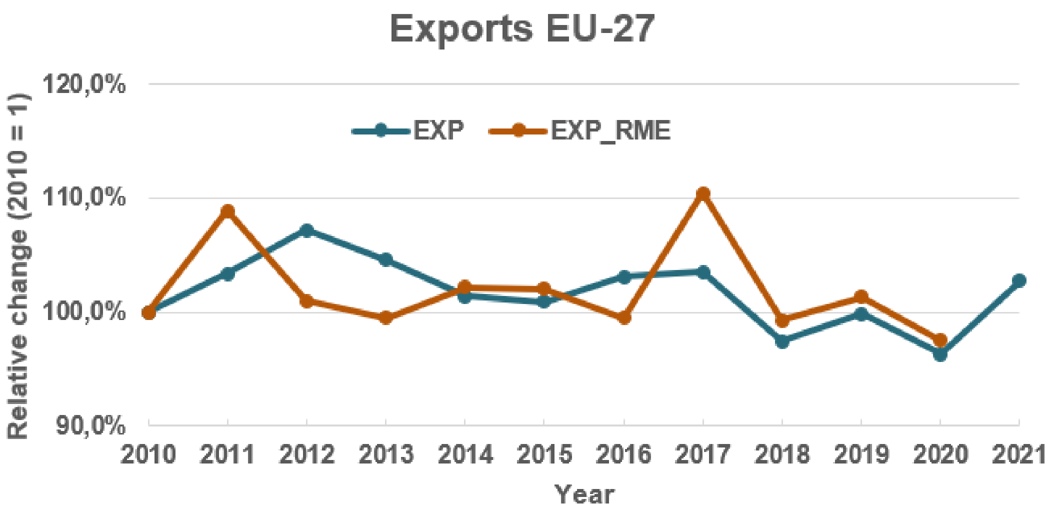
The reason for this might include changes (benchmarks) in the national accounts based on improvement and adjustments to the methodology over time. This implies that only recent trade ratios should be used in estimating the material footprint in order to allow for consistency in the calculation approach. As a result, the further analysis focused on the time window from 2010 to 2020. The relative annual changes in IMP vs. IMP_RME and EXP vs. EXP_RME are provided in Figure 2.2 and Figure 2.3.

Figure 2.2 Relative change of direct imports (IMP) and indirect imports in raw material equivalents (IMP_RME) from 2010 to 2020 using Eurostat data.



Note: **IMP: Direct imports; IMP_RME: Imports in raw material equivalents (RME)**
Source: Eurostat data (ENV_AC_MFA and ENV_AC_RME)

Figure 2.3 Relative change of direct exports (EXP) and indirect exports in raw material equivalents (EXP_RME) from 2010 to 2020 using Eurostat data.



Note: **EXP: Direct exports; EXP_RME: Exports in raw material equivalents (RME)**
Source: Eurostat data (ENV_AC_MFA and ENV_AC_RME)

Figure 2.2 highlights that the relative changes in direct and indirect imports over the 10-year time period from 2010 to 2020 are generally well aligned. Figure 2.3 shows the same relative changes for direct and indirect exports and, with the exception of years 2011 and 2017, these trends are also fairly well aligned. Data for direct imports and exports are already available from the Eurostat early estimates for 2021 (with data for 2022 forthcoming around July 2023). Hence, using this approach would allow nowcasting the RMC at EU-27-level by one year (T+1 year). Using the relative change in direct imports and exports for the last year assumes that the economic structure does not change significantly from one year to another (i.e., the material rucksack stays constant).

Should the trade ratios not be as stable as in Table 2.2, an alternative approach would be to use the historical moving average in the ratios IMP/IMP_{RME} and EXP/EXP_{RME} over the last 10 years when nowcasting data for t+1. As shown in Table 2.2, the import and export ratios are relatively constant over this time period. For RMC total they are found at 0.51 for IMP/IMP_{RME} and 0.33 for EXP/EXP_{RME} (2010-2020). Assuming these ratios also for t+1 allows calculation of the indirect imports and exports.

The stability of the import and export ratios suggests to use the last available year when nowcasting the material footprint in order to ensure consistency with previous RME calculations approaches and assuming that the economic structure does not change much from one year to another.

2.2.3 Comparison of possible approaches and recommendation

An overview of possible approaches to nowcast the material footprint including the advantages and disadvantages is provided in Table 2.3.

Table 2.3 Comparison of different RMC nowcasting approaches

Approach	Detail	Nowcast year	Advantage	Disadvantage
1. Use of predictors and RME coefficients	DE: predictors of production for materials used in large quantities (i.e., crops and crops residues, wood, metal ores, non-metallic minerals, coal and other solid energy materials/carriers, liquid and gaseous energy materials/carriers) (ECORYS, 2013). RME: Trade data are nowcasted using Comext statistics[18] (t+2months) (ECORYS, 2013). RME coefficients are derived following approximately the Eurostat RME model (Eurostat, 2012).	Depends on availability of national accounts/SUTs	Aligned with RME country tool.	Method to estimate RME coefficients is very time-intensive and therefore beyond the scope of this task. Early estimates for DE and direct imports & exports are already provided by Eurostat.
2. Regression models	Regression-based nowcast based on historical trends using a number of dependent variables (i.e., population, ratio of price-adjusted gross capital formation/price adjusted domestic aggregate demand, and ratio of price-adjusted imports/exports) (UBA, 2019).	T+multiple years	Can be applied across countries (if predictors can be found).	RMC data at country-level are not provided for individual material categories limiting the selection of predictors. Short-term economic changes such as COVID (2020) or the economic downturn (2008) make this approach challenging.
3. Annual change rates of physical imports/exports	DE: Data directly taken from Eurostat EW-MFA by material category (early estimates). RME: Data on direct imports and	T+1	Based on Eurostat EW-MFA early estimates and RME coefficients from the last year.	Limited to countries for which imports and exports in RME are published.

18 https://ec.europa.eu/eurostat/web/international-trade-in-goods/data/focus-on-comext

Approach	Detail	Nowcast year	Advantage	Disadvantage
	exports from Eurostat EW-MFA by material category (early estimates). The relative changes in direct imports/exports from 2019 to 2020 were assumed for the RME of import and exports. This is based on the observation that the changes of direct imports/exports often follow the indirect imports/exports (in RME). (UBA, 2022)		Can be easily applied to future years by EEA and high transparency of the underlying method. *(Recommended approach)*	

Based on this review of different approaches for nowcasting the material footprint, the authors of this report recommend Option 3 using historical trade relationships in combination with Eurostat EW-MFA early estimates of domestic extraction for nowcasting the indicator one year into the future.

Option 3 is transparent, based on existing Eurostat datasets, and easily implementable within Excel by the EEA. The approach is based on the assumption that the historical RME coefficient(s) also apply to a future year (i.e., the economic structure does not change significantly from one year to the next). However, given data availability the nowcasts can only be provided for the EU-27 and selected EU member countries for which RME import/export estimates are available (i.e., the following 15 countries: Belgium, Denmark, Germany, Estonia, France, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Austria, Portugal, Romania, and Switzerland)[19]. We also acknowledge that global value chains changed substantially in the last few years due to the disruption induced by COVID and sanctions to Russia (particularly relevant for raw materials). Such sudden shifts (within one year) are difficult to reflect in nowcasts in general and also using the approach based on historical trade ratios.

In contrast, the Eurostat RME model is based on a specific IOT-based calculation model which is denoted as ADTA-IO model. Adapting the Eurostat RME model for future years is complex and beyond the scope of this ETC-project (Option 1). We note that some coefficients in the RME model are using a monetary unit and considering the high inflation in 2022 and 2023, the method should correct for this in the RME-conversion factors. However, final demand (changes in final household consumption and gross capital formation) might be adjusted, while assuming that the structure of the economy remains constant (see also the indicator 'EEA consumption footprint').

Methods using regression analysis (Option 2) seem not feasible as the RME coefficients are already model based and data availability at country-level do not allow for a split into individual material categories, hence, limiting the choice of predictors. However, this approach is currently being tested in working paper 2 to develop outlooks which would include regression-based estimates of the previous and current year.

2.2.4 Implementation of the approach by Eurostat

The approach based on the annual change rates of physical imports/exports described above (option 3) has been discussed with Eurostat in summer 2023 and was subsequently reviewed and implemented by Eurostat into the RME statistics (env_ac_rme)[20] for the EU-27 and all member countries.

Methodological details can be found in the Eurostat metadata as follows:

19 Imports and exports in RME by MS level are missing for Bulgaria, Czechia, Ireland, Greece, Spain, Croatia, Cyprus, Latvia, Hungary, Poland, Slovenia, Slovakia, Finland, and Sweden. Finally, RME import/export estimates for 2020 are only available for the EU-27, Italy, and Luxembourg.

20 https://ec.europa.eu/eurostat/databrowser/view/env_ac_rme/default/table?lang=en

"The early estimate for RMC is done as follows: First, the imports and exports in raw material equivalents are estimated by applying the annual change rates of physical imports and exports as derived from economy-wide material flow accounts (at the level of main material categories). In a second step, the estimated imports in raw material equivalent are added to domestic extraction and exports in raw material equivalent are deducted to arrive at RMC." (Source: Eurostat env_ac_rme metadata)[21].

2.3 EEA consumption footprint

2.3.1 Nowcasting methodology

The consumption footprint refers to the environmental impacts (e.g., climate change, land-use, water use, acidification, etc.) resulting from the consumption by EU citizens of goods and services, whether produced within or outside the EU. To monitor the EU's consumption footprint, this indicator uses a single weighted and normalized score that represents different types of impacts on the environment and climate caused by consumption of goods and services by EU citizens.

The global distribution of pressures and effects related to the final EU-27 consumption have been calculated using an environmentally extended multiregional input-output model based on EXIOBASE v.3.8.2 data (Stadler et al., 2021). For this purpose, environmentally extended industry-by-industry tables were used. The calculation is based on the following formula:

$$E^T = \langle e^{int} \rangle . x = \langle e^{int} \rangle . (I - A)^{-1} . y$$

with:

- E^T: environmental footprint
- $\langle e^{int} \rangle$: environmental effect intensity vector, the amount of the effect directly caused by the production of a product group
- x: sectoral (monetary) output based on final demand
- $(I - A)^{-1}$: Leontief inverse, representing the economic structure of the supply chain network
- y: final demand, EU27

Applying the formula gives individual results for each environmental extension available from the EXIOBASE-dataset. In a next step, these extensions are translated into environmental impact categories[22] according to the Environmental Footprint (EF) method v3.2. Translating the 528 unique environmental extension lines into the 16 impact categories of the EF-method requires a conversion through characterization factors.

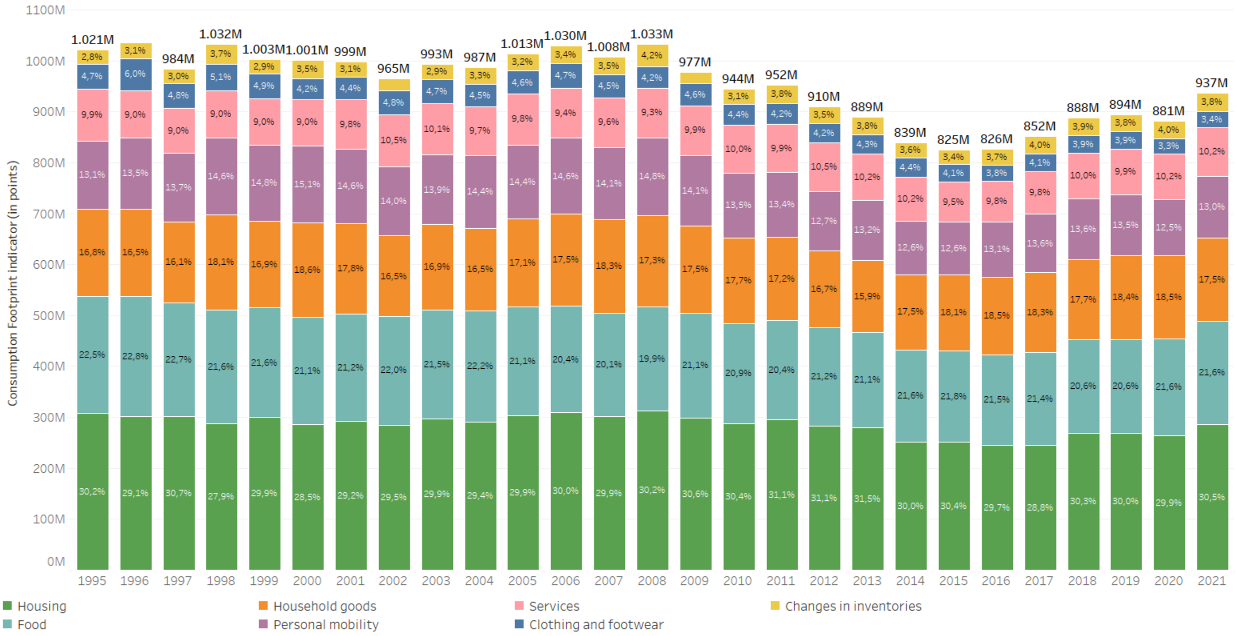
An important remark here is that the EF method defines characterization factors for more emissions and resources extracted than available in EXIOBASE. For some environmental impacts, like climate change, the coverage of EXIOBASE is quite complete. For other impacts however, like toxicity, EXIOBASE includes only a very limited selection of emissions. No information, and thus no extension lines, is available in EXIOBASE to estimate the impact categories ozone depletion and ionising radiation.

21 https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_rme_esms.htm

22 Acidification, climate change, ecotoxicity (freshwater), eutrophication (freshwater), eutrophication (marine), eutrophication (terrestrial), human toxicity (cancer), human toxicity (non-cancer), ionizing radiation, land use, ozone depletion, particulate matter, photochemical ozone formation, resource use (fossil), resource use (mineral and metals), and water use.

The consumption footprint indicator is a single score value expressed in points. Converting the different environmental impact categories to this single score requires normalisation and weighting. The normalisation and weighting allow expressing all environmental impacts into a single score.

Figure 2.4: Consumption Footprint indicator of total final demand in EU27, per consumption domain, 2010-2021. ETC-CE calculations based on EXIOBASE v3.8.2.



Source: ETC CE calculations based on Exiobase v. 3.8.2 (Stadler et al., 2021).

The current calculation of the EU-27 environmental footprint covers the period 1995-2021 (see Figure 2.4) (EEA, 2022). The nowcasting methodology assumes that the economic structure (represented by the Leontief inverse) and the environmental effect intensity vector (i.e., $\langle e^{int} \rangle$) remain constant during the period of nowcasting. Considering the relatively short time frame of one to two additional years, the nowcasting focusses only on including the changes in EU-27 final demand (at EU MS level).

Meaning, the nowcast of the environmental footprint implies:

- An update in final demand expenditures based on available data from Eurostat; and
- Deflating these expenditures of final demand back to the latest data years prices.

$$\boldsymbol{E}_{t+1}^{T} = \langle e^{int} \rangle_t . (I - A_t)^{-1} . \boldsymbol{y}_{t+1}$$

The underlying datasets determining the EU-27 total final demand, and MS-level final demand are described in Table 2.4 below.

Table 2.4 Datasets determining the EU-27 total and MS-level final demand

Name	Online data code	Currently available data	Dissemination of data
Final consumption expenditures of **households**, **non-profit institutions serving households**, **governments**, **gross fixed capital formation**	nama_10_gdp	1995-2022 (last update 23/10/2023; at MS-level)	T+2 and T+9 months
Final consumption expenditures of **households** by consumption purpose	nama_10_co3_p3	1995-2021 (last update 26/10/2023; at MS-level)	T+9 and T+21 months
General **government** expenditure by function (COFOG)	gov_10a_exp	1995-2021 (last update 21/07/2023; at MS-level)	T+14 months, frequent updates after validations
Gross fixed capital formation by AN_F6 asset type	nama_10_an6	1995-2022 (last update 23/10/2023; at MS-level)	T+2 and T+9 months

Total final demand data (at MS-level) for households, non-profit institutions serving households (NPISH), governments, gross fixed capital formation (GFCF), and the changes in inventories and acquisitions less disposals of valuables is already available in T+2 months. These totals are corrected by an update in T+9 months.

The distribution of consumption expenditures by NPISH, governments and gross fixed capital formation across consumption domains and the conversion factors to convert from purchasers to basic prices are assumed to equal the latest data year. This assumption implies a risk in converting current prices into the prices of the latest data year: very unbalanced inflation rates across consumption domains could give rise to increased uncertainty.

Eurostat data on the final consumption expenditures of households by consumption purpose are available in T+9 months and are updated in T+21 months. Making use of this data decreases the uncertainty in two ways. First, the distribution across consumption domains is no longer fixed to the latest data year. Changes in consumption volumes across product groups are considered. Second, the conversion from current to prices of the latest data year are made at the level of the individual consumption domains, which include the potential unbalanced inflation rates across consumption domains.

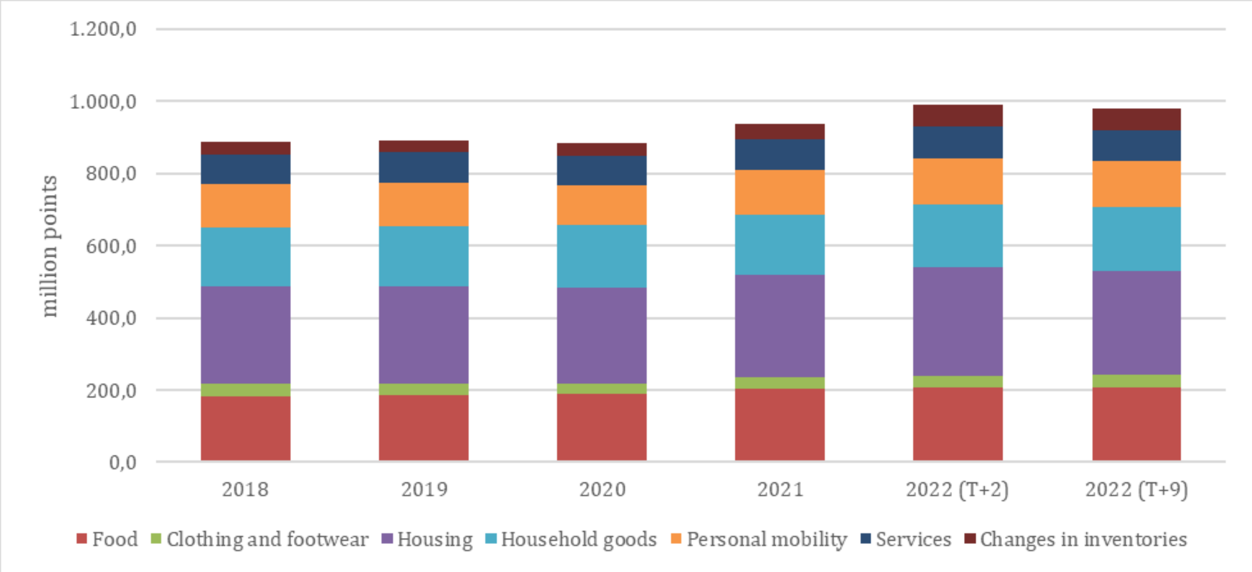
The data on general government expenditure by function and on gross fixed capital formation by asset type are merely informative. Although these datasets are not used in the nowcasting methodology, a qualitative check is required to spot large changes across functions or asset types, respectively. As the nowcasting methodology only includes changes in total final demand, the changes across functions or asset types are ignored. In case changes in growth rates differ between functions or asset types, the result of the nowcasting methodology should be flagged.

2.3.2 Suggested implementation of the approach

The nowcasting calculations are carried out in an excel-based Consumption Footprint indicator 'CFI-tool' following the reasoning described in the previous section. The CFI-tool estimates the final demand of the year of nowcasting. Based on this estimated final demand the CFI is calculated.

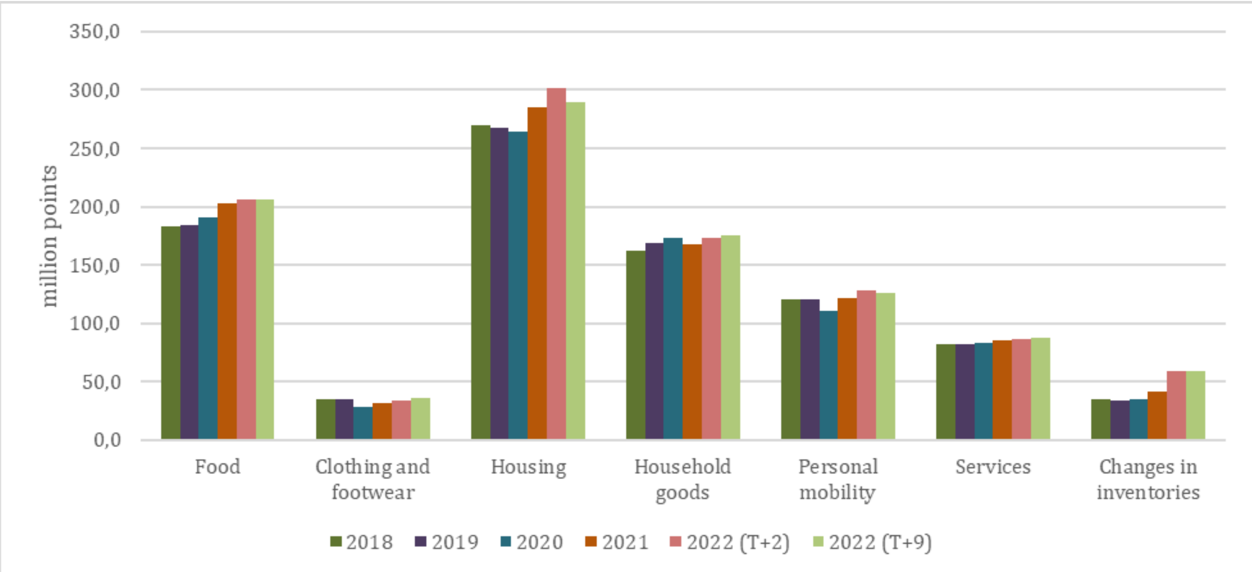
The results for the nowcasting of 2022-data is presented in Figure 2.5 and Figure 2.6. The nowcasted value is 981 million points in 2022, including the final consumption expenditures of households by consumption purpose data (T+9). Not making use of this dataset results in an estimate of 989 million points (T+2). This difference is the result from different change rates per consumption domain which are not accounted for in the nowcasting after T+2 months. Because the impact from household consumption is two-third of the total Consumption Footprint indicator, it is advised to improve the nowcasting results in T+9 months (or to wait for applying the nowcasting till T+9 months).

Figure 2.5 Consumption Footprint indicator of total final demand in EU27, per consumption domain, 2010-2021, plus nowcasted estimate for 2022 based on T+2 and T+9 data.



Source: ETC CE calculations based on EXIOBASE v3.8.2 (Stadler et al., 2021).

Figure 2.6 Consumption Footprint indicator of total final demand in EU27, per consumption domain, 2010-2021, plus nowcasted estimate for 2022 based on T+2 and T+9 data.



Source: ETC CE calculations based on EXIOBASE v3.8.2 (Stadler et al., 2021).

2.4 Waste generation and decoupling

Waste generation

Eurostat's dataset '*Generation of waste by waste category, hazardousness and NACE Rev. 2 activity* - ENV_WASGEN' is a multi-dimensional data cube including several hundreds of data points per time period and geographical entity. It includes the following six dimensions:

- Geopolitical entity (reporting);
- Time – reference year;

- Hazard class;
- Waste categories;
- Statistical classification of economic activities in the European Community (NACE Rev. 2) plus households;
- Unit of measure

The first reference year is 2004, and data are reported for the even years only.

2.4.1 Nowcasting methodology

Two approaches have been investigated for nowcasting the year 2022 of the indicator 'waste generation':

- the first is based on regression models and builds on the methodology of Eurostat's EW-MFA early estimates (Eurostat E2, 2021);
- the second applies the annual change rate in relevant drivers of waste generation.

It has to be noted that the annual change rate methodology is used in both of the approaches for gap filling odd years of the waste generation time series up to the year 2021.

An additional method that might be considered in future work is a regression analysis based on parametric and semi/non parametric models, the latter possibly capturing non linearities of time series and country cross correlation, especially in a longitudinal setting (when considering the EU as a whole in a panel data framework) (Abadie, 2005; Bai, 2009; Ertur and Musolesi, 2017; Gioldasis et al., 2023; Mazzanti and Musolesi, 2014; Cardot and Musolesi, 2020). Notwithstanding the limited feasibility of regression analysis, the statistical benefits of a panel data structure (a matrix of all European countries for all available years) might be considered in the future to analyze the overall European nowcasting case. The panel data structure allows considering the role of country heterogeneity, cross correlation, under parametric and semi parametric models. The latter allows better disentangling the role of socio-economic drivers (e.g., GDP) and time related effects (like policies, shocks), also considering non-additivity of the relevant underpinning factors.

Ideally, the granularity by MS, by waste category and by economic activity of Eurostat's waste generation dataset would allow to perform the nowcasting activities according to a bottom-up approach, i.e., the calculations could be carried out for each country at a disaggregated level (either at waste category or economic activity level) and then aggregated to make the estimate for the total EU level. A bottom-up perspective should ensure more accurate results than total-level estimations.

If a bottom-up estimation process is adopted, the first step is to identify the dependent variables for waste generation. As mentioned above, the waste generation statistics are available both by industry and by waste category. It is straightforward to use as dependent variable **waste generation by industry** as this option allows a more direct link between waste generation and its drivers. Indeed, if one has the DPSIR model – Driving forces-Pressures-State-Impact-Response – as conceptual reference framework, an explicit causal linkage can be made between the anthropogenic activities (driving forces) that directly interact with the natural environment through physical exchanges that produce stress (pressures).

Table 2.5 provides the dimension 'NACE' of the Eurostat waste dataset, i.e., the list of industries, plus households, which generate waste. Moreover, the **economic predictors** (i.e., the independent variable of potential models) are connected to the generation of waste by industry in the Table. Predictors for waste generation are identified according to their availability and timeliness:

- Gross value added in volumes (Eurostat source: NAMA_10_A10; NAMA_10_A64);

- Agricultural output in volumes (Eurostat source: AACT_EAA03);
- Volume index of production (Eurostat source: STS_INPR_A; STS_COPR_A; STS_SEPR_A; STS_SETU_A);
- Production value of NACE G4677 'Wholesale of waste and scrap' (Eurostat source: SBS_NA_DT_R2);
- Final consumption expenditure of households (Eurostat source: NAMA_10_GDP).

Except for the datasets '*National accounts aggregates by industry up to NACE A*64* (NAMA_10_A64)' and '*Structural business statistics* (SBS_NA_DT_R2)', which are updated more slowly, the year 'T' is available for the other datasets in March of the following year (i.e., at 'T + 3 months').

Table 2.5 Predictors for nowcasting waste generation and for estimating odd years.

Dependent variable: Generation of waste by NACE		Predictors					
NACE_R2 (Codes)	*NACE_R2 (Labels)*	*Indicator*	*unit of measure*	*Eurostat data set name*	*Eurostat data set code*	*Eurostat release calendar*	*note*
A	Agriculture, forestry, and fishing	GVA at basic prices of NACE [A] Agriculture, forestry, and fishing	volumes	Gross value added and income by A*10 industry breakdowns	NAMA_10_A10	T+2 and T+9	
		Production value at basic price [PROD_BP], Agricultural output [16000]	volumes	Economic accounts for agriculture - values at constant prices (2015 = 100)	AACT_EAA03	T+5 (II estimates)	EU as of 2005
B	Mining and quarrying	GVA at basic prices of NACE [B] Mining and quarrying	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [B] Mining and quarrying	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C	Manufacturing	GVA at basic prices of NACE [C] Manufacturing	volumes	Gross value added and income by A*10 industry breakdowns	NAMA_10_A10	T+2 and T+9	
		[PROD] Volume index of production of [C] Manufacturing	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C10-C12	Manufacture of food products; beverages and tobacco products	GVA at basic prices of NACE [C10-C12] Manufacture of food products; beverages and tobacco products	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [C10-C12] Manufacture of food products; beverages and tobacco products	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C13-C15	Manufacture of textiles, wearing apparel, leather, and related products	GVA at basic prices of NACE [C13-C15] Manufacture of textiles, wearing apparel, leather, and related products	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [C13-C15] Manufacture of textiles, wearing apparel, leather and related products	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	GVA at basic prices of NACE [C16] Manufacture of wood and of products of wood and cork, except furniture; …	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [C16] Manufacture of wood and of products of wood and cork, except furniture; …	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C17_C18	Manufacture of paper and paper products; printing and reproduction of recorded media	GVA at basic prices of NACE [C17] Manufacture of paper and paper products and [C18] Printing and reproduction of recorded media	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [C17_C18] Manufacture of paper and paper products; printing and reproduction of recorded…	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C19	Manufacture of coke and refined petroleum products	GVA at basic prices of NACE [C19] Manufacture of coke and refined petroleum products	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	

Dependent variable: Generation of waste by NACE		Predictors					
NACE_R2 (Codes)	***NACE_R2 (Labels)***	***Indicator***	***unit of measure***	***Eurostat data set name***	***Eurostat data set code***	***Eurostat release calendar***	***note***
		[PROD] Volume index of production of [C19] Manufacture of coke and refined petroleum products	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C20-C22	Manufacture of chemical, pharmaceutical, rubber and plastic products	GVA at basic prices of NACE [C20] Manufacture of chemicals and chemical products and [C22] Manufacture of rubber and plastic products	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [C20_C21] Manufacture of chemicals and chemical products; basic pharmaceutical..., [C22] Manufacture of rubber and plastic products	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C23	Manufacture of other non-metallic mineral products	GVA at basic prices of NACE [C23] Manufacture of other non-metallic mineral products	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [C23] Manufacture of other non-metallic mineral products	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C24_C25	Manufacture of basic metals and fabricated metal products, except machinery and equipment	GVA at basic prices of NACE [C24_C25] Manufacture of basic metals and fabricated metal products, except machinery…	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [C24_C25] Manufacture of basic metals and fabricated metal products, except machinery…	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C26-C30	Manufacture of computer, electronic and optical products, electrical equipment, motor vehicles and other transport equipment	GVA at basic prices of NACE [C26] Manufacture of computer, electronic and optical products, [C27] Manufacture of electrical equipment, [C28] Manufacture of machinery and equipment n.e.c., [C29_C30] Manufacture of motor vehicles, trailers, semi-trailers and of other transport	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [C26_C27] Manufacture of computer, electronic and optical products; manufacture of..., [C28] Manufacture of machinery and equipment n.e.c., [C29_C30] Manufacture of motor vehicles, trailers, semi-trailers and of other transport	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
C31-C33	Manufacture of furniture; jewelry, musical instruments, toys; repair and installation of machinery and equipment	GVA at basic prices of NACE [C31-C33] Manufacture of furniture; jewelry, musical instruments, toys; repair and…	volumes	National accounts' aggregates by industry (up to NACE A*64)	NAMA_10_A64	T+9 and T+21	
		[PROD] Volume index of production of [C31-C33] Manufacture of furniture; jewelry, musical instruments, toys; repair and...	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
D	Electricity, gas, steam, and air conditioning supply	[PROD] Volume index of production of [D] Electricity, gas, steam, and air conditioning supply	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	
E	Water supply; sewerage, waste management and remediation activities						
E36_E37_E39	Water collection, treatment, and supply; sewerage; remediation activities and other waste management services	[PROD] Volume index of production of [E36] Water collection, treatment, and supply	[I10] Index, 2015=100	Production in industry - annual data	STS_INPR_A	T+3	

Dependent variable: Generation of waste by NACE		Predictors					
NACE_R2 (Codes)	***NACE_R2 (Labels)***	***Indicator***	***unit of measure***	***Eurostat data set name***	***Eurostat data set code***	***Eurostat release calendar***	***note***
E38	Waste collection, treatment, and disposal activities; materials recovery						
F	Construction	GVA at basic prices of NACE [F] Construction	volumes	Gross value added and income by A*10 industry breakdowns	NAMA_10_A10	T+2 and T+9	
		[PROD] Volume index of production of NACE [F] Construction	[I10] Index, 2015=100	Production in construction - annual data	STS_COPR_A	T+3	
G-U_X_G4677	Services (except wholesale of waste and scrap)	[PROD] Volume index of production of [G-N_STS] Services required by STS regulation	[I10] Index, 2015=100	Production in services - annual data	STS_SEPR_A	T+3	18/27 EU MS + EU27
		[TOVT] Index of turnover of [G-N_STS] Services required by STS regulation	[I10] Index, 2015=100	Turnover in services - annual data	STS_SETU_A	T+3	
G4677	Wholesale of waste and scrap	[V12120] Production value of [G4677] Wholesale of waste and scrap	million euro	Annual detailed enterprise statistics for trade (NACE Rev. 2 G)	SBS_NA_DT_R2	T+12	data as of 2005
EP_HH	Households	[P31_S14] Final consumption expenditure of households	volumes	GDP and main components (output, expenditure, and income)	NAMA_10_GDP	T+3	
		[B1GQ] Gross domestic product at market prices	volumes	GDP and main components (output, expenditure, and income)	NAMA_10_GDP	T+3	
TOTAL_HH	All NACE activities plus households	[B1GQ] Gross domestic product at market prices	volumes	GDP and main components (output, expenditure, and income)	NAMA_10_GDP	T+3	

Source: ETC CE compilation based on various Eurostat data sets. The table ist structured according to the generation of waste NACE Rev. 2 activity [ENV_WASGEN].

The availability of these predictors would allow undertaking the nowcasting process according to regression **models**. The following list of models is proposed:

- Regression of absolute values (M1):

$$y_t = a + bx_t$$

- Regression of absolute changes (M2):

$$y_t - y_{t-1} = a + b\,(x_t - x_{t-1})$$

- Regression of relative changes (M3):

$$y_t/y_{t-1} = (1+ (a + b\,(x_t/x_{t-1} - 1))$$

- Regression of logged values (M4):

$$y_t\,/y_{t-1} = \exp\,(a\ b\,(\ln x_t - \ln x_{t-1}))$$

where "y" is the dependent variable (waste generation), "x" is the independent variable (predictor), "a" is a constant term, and "b" is the coefficient for the predictor.

A fifth model is also used, annual relative change in predictor (M5):

$$y_t = y_{t-1} * x_t / x_{t-1}$$

which should be used if the four regression models do not provide satisfactory results.

The predictor variables chosen are country- and industry-specific. They have been selected with the help of an analysis conducted along this ETC task.

However, at this level of detail, predictors may:

- not perform sufficiently well for waste generated in some industries, such as 'D Electricity, gas, steam and air conditioning supply', 'E36, E37, E39 Water collection, treatment and supply; sewerage; remediation activities and other waste management services', 'F Construction', 'G-U except G4677 Services (except wholesale of waste and scrap)', 'G4677 Wholesale of waste and scrap';
- not show any sufficient correlation with waste generated within a number of countries;
- not be relevant, or available at all, for some industries such as 'E Water supply; sewerage, waste management and remediation activities', 'E38 Waste collection, treatment and disposal activities; materials recovery'.

In addition:

- an approach which is carried out at a detailed level of disaggregation (by MS and by industry) requires the data availability of complete Eurostat datasets of both data on waste generation by economic activity and on its respective predictor at MS-level.

Therefore, waste generation estimates are undertaken for each country using a twofold breakdown of the dimension 'economic activities' in Eurostat env_wasgen: total economic activity (which uses GDP as predictor) and household (which uses Final consumption expenditure of households as predictor).

Before performing the regressions and given that the predictors' time series provide – differently from the waste generation dataset – data for all years (even and odd years), the **estimation of the odd years**

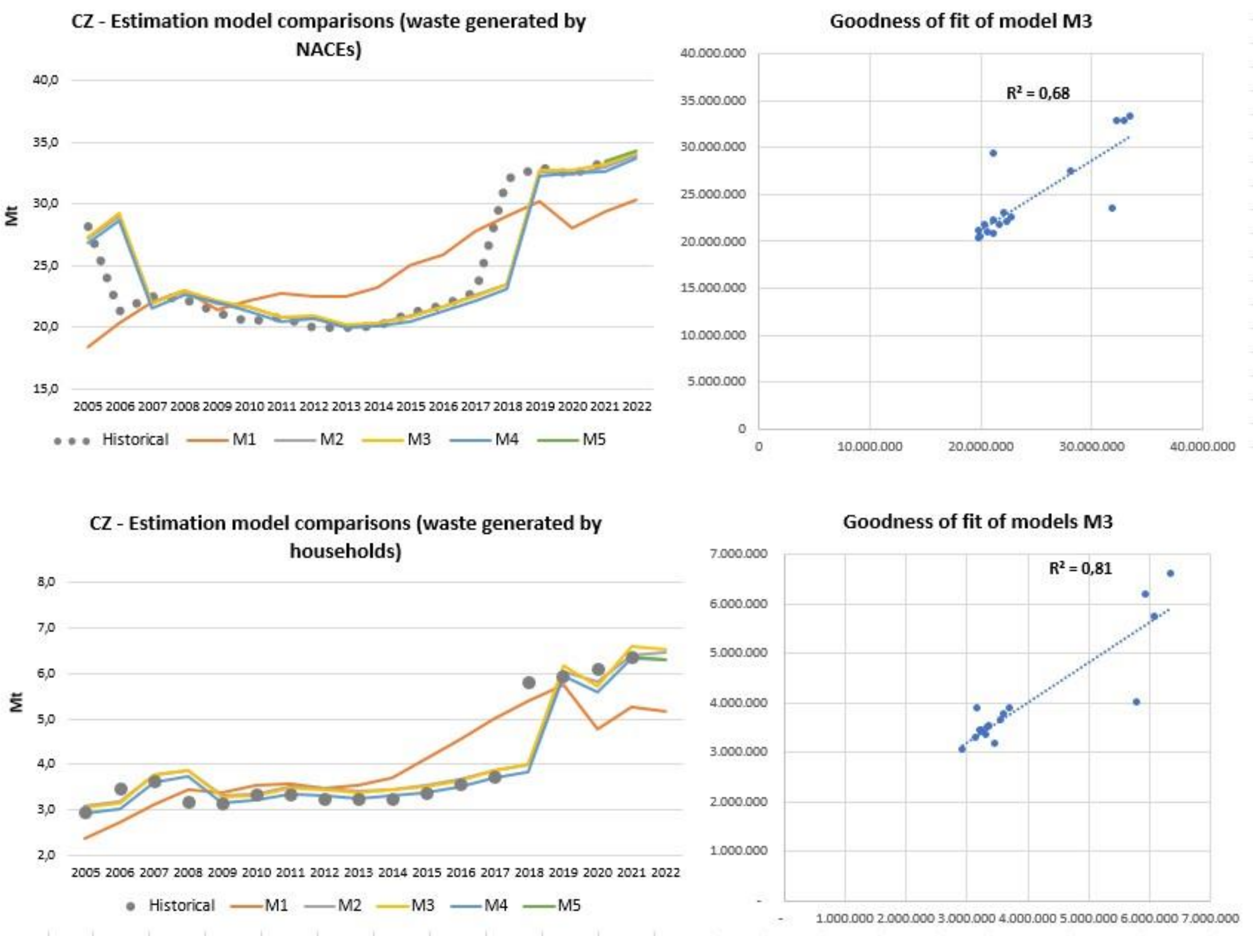
of waste generation statistics is carried out. The methodology used for estimating the odd years is the annual relative change in the predictor[23].

Once datasets are complete, i.e., odd and even years for waste generation are available as for its predictors, the regressions can be implemented.

Regression models are implemented at country level to nowcast waste generation by industries (with GDP as independent variable) and waste generation by households (with Final consumption expenditure of households as independent variable). The models' estimates for a single country can be analysed within charts, one chart for waste generated by all NACEs and one for waste generated by households (see example below). These charts show how well the fitted values from each model type compare to the historical series of waste generation for the country under review. In addition, for each model estimated, a scatter plot of the fitted values against the historical data on waste generation (including a trendline) is provided to give an indication of goodness of fit.

Results on how the five models for industries and households perform for Czechia are shown in Figure 2.7, as an example.

Figure 2.7 Estimation model comparisons for Czechia



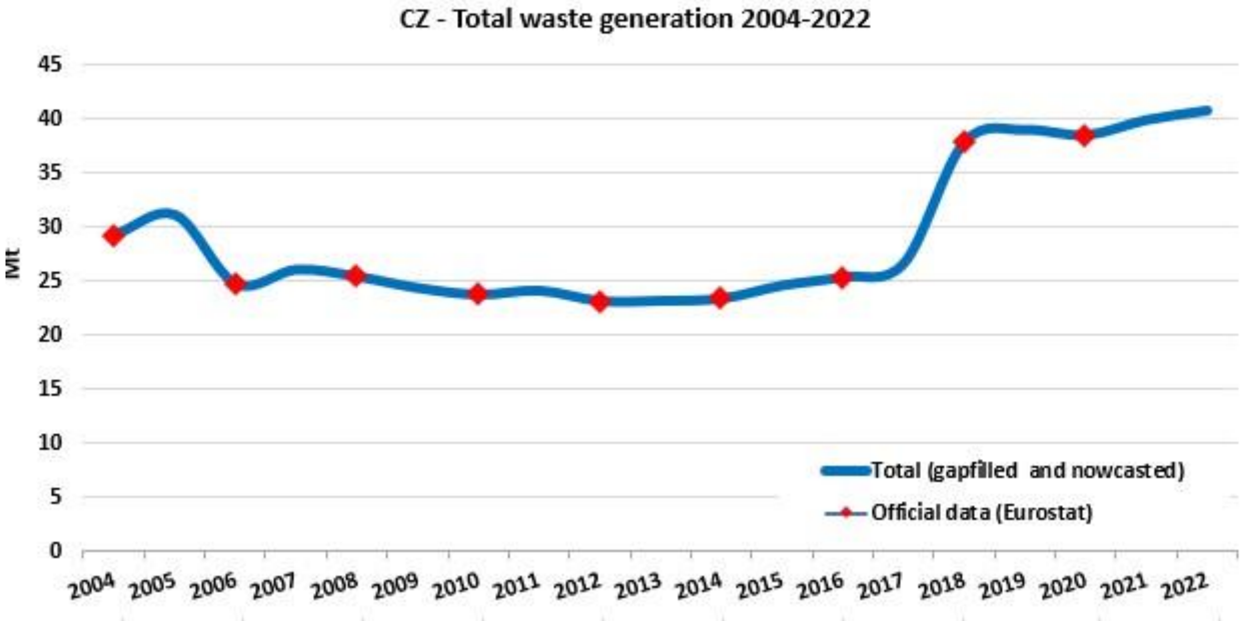
Source: ETC CE calculations based on Eurostat waste generation statistics (ENV_WASGEN).

23 A further option to investigate for estimating odd years could be estimating the elasticity for even years and then apply it to estimate the value for odd years.

The two charts on the left compare the estimation models, i.e., how well the fitted values from each model type compare to the historical waste generation time series. In addition, for the model selected (in this case 'regression of relative changes - M3', both for waste generation by all economic activities and households), a scatter plot of the fitted values against the historical time series with a trendline to give an indication of goodness of fit is provided (charts on the right).

Figure 2.8 shows results for total waste generation in Czechia for the period 2004-2022.

Figure 2.8 Results for total waste generation in Czechia: gap filling odd years and nowcasting 2021 and 2022.



Source: ETC CE calculations based on Eurostat waste generation statistics (ENV_WASGEN).

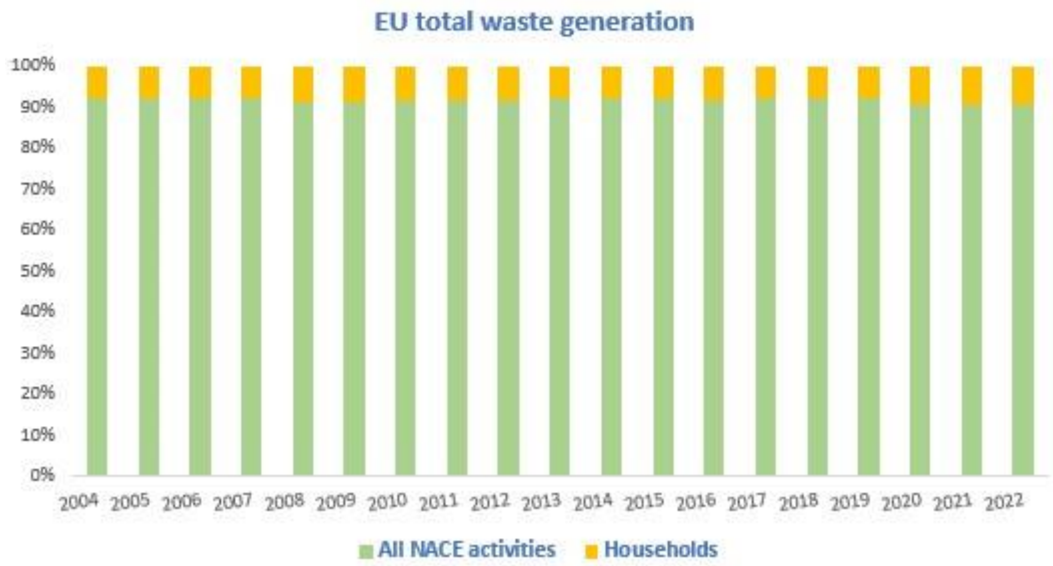
Figure 2.9 presents results for total waste generation in EU, calculated as sum of Member State's results. This Figure includes the interpolation of odd years which is usually undertaken for gap filling the waste statistics time series.

Figure 2.9 Gap filling and nowcasting waste generation. Results for total waste generation in EU

Source: ETC CE calculations based on Eurostat waste generation statistics (ENV_WASGEN).

Moreover, Figure 2.10 shows how these results are distributed between the two main components of waste generation, all industries and households.

Figure 2.10 Distribution of final results for EU waste generation for the period 2004-2022 between economic activities and households.



Source: ETC CE calculations based on Eurostat waste generation statistics (ENV_WASGEN).

Detailed results of gap filling and nowcasting for EU and Member States from 2004 to 2022 are presented in Table 2.6 (Eurostat data in black figures; ETC CE estimates in blue figures).

Table 2.6 Waste generation for the EU-27 and Member States, 2004-2022 (*million tonnes*)*

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
European Union	**2.248,8**	**2.318,5**	**2.276,1**	**2.374,3**	**2.144,8**	**2.061,1**	**2.212,9**	**2.259,7**	**2.242,5**	**2.242,4**	**2.243,8**	**2.298,4**	**2.258,9**	**2.332,4**	**2.338,2**	**2.389,5**	**2.153,9**	**2.274,1**	**2.351,1**
Belgium	52,8	54,0	59,4	61,5	48,6	47,8	61,3	62,3	53,8	54,2	58,0	59,1	63,2	64,2	68,2	69,7	68,1	72,3	74,7
Bulgaria	201,0	215,2	162,9	173,9	167,6	162,0	167,4	170,9	161,3	160,3	179,7	185,8	120,5	123,8	129,8	135,1	116,4	125,3	129,5
Czechia	29,3	31,1	24,7	26,1	25,4	24,4	23,8	24,1	23,2	23,2	23,4	24,6	25,4	26,6	37,8	39,0	38,5	39,9	40,6
Denmark	12,6	12,9	14,7	14,9	15,2	14,4	16,2	16,4	16,7	16,9	20,8	21,3	21,0	21,6	21,4	21,8	20,1	21,5	21,9
Germany	364,0	366,7	363,8	373,5	372,8	353,6	363,5	377,1	368,0	369,6	387,5	393,5	400,1	410,3	405,5	410,1	401,2	413,2	421,5
Estonia	20,9	22,8	18,9	20,4	19,6	16,7	19,0	20,4	22,0	22,3	21,8	22,2	24,3	25,7	23,2	24,1	16,2	17,5	17,3
Ireland	24,5	25,9	29,6	31,2	22,5	21,4	19,8	20,0	12,7	12,8	15,2	18,6	15,3	16,6	14,0	14,7	16,2	18,5	20,3
Greece	33,3	33,7	51,3	53,0	68,6	65,8	70,4	63,4	72,3	70,5	69,8	69,6	72,3	73,2	45,2	46,1	28,4	30,6	32,5
Spain	160,7	166,6	160,9	166,7	149,3	143,7	137,5	136,0	118,6	116,6	110,5	114,6	129,0	132,8	137,8	140,3	105,6	111,6	117,4
France	296,6	301,7	312,3	319,9	345,0	336,0	355,1	362,4	344,4	346,4	324,5	328,2	322,7	329,8	343,3	349,6	310,4	329,9	338,1
Croatia	7,2	7,5	5,4	5,7	4,2	3,8	3,2	3,2	3,6	3,6	3,7	3,8	5,4	5,5	5,5	5,7	6,0	6,8	7,2
Italy	139,8	141,1	155,0	157,2	179,3	171,0	158,6	159,5	154,4	151,4	157,9	159,4	163,8	166,5	172,5	173,3	174,9	186,4	193,6
Cyprus	2,2	2,3	1,2	1,3	1,8	1,8	2,4	2,4	1,9	1,7	2,0	2,0	2,5	2,6	2,3	2,4	2,2	2,4	2,5
Latvia	1,3	1,4	1,9	2,1	1,5	1,3	1,5	1,5	2,3	2,4	2,6	2,7	1,9	2,0	1,8	1,8	2,9	3,0	3,1
Lithuania	7,0	7,6	6,4	7,1	6,3	5,4	5,6	5,9	5,7	5,9	6,2	6,3	6,7	7,0	7,1	7,4	6,7	7,1	7,2
Luxembourg	8,3	8,5	8,4	9,0	9,6	9,3	10,4	10,6	8,4	8,7	7,1	7,2	10,0	10,2	9,0	9,2	9,2	9,7	9,8
Hungary	24,7	25,7	22,3	22,4	16,9	15,8	16,7	17,0	16,3	16,6	16,7	17,3	15,9	16,6	18,4	19,3	17,2	18,3	19,2
Malta	3,1	3,3	2,9	3,0	2,1	2,1	1,4	1,4	1,5	1,5	1,7	1,8	2,0	2,2	2,5	2,7	3,5	3,9	4,2
Netherlands	92,4	94,2	99,2	102,7	102,6	99,0	121,1	122,9	121,2	121,0	132,4	135,0	141,0	145,1	145,2	148,0	125,1	132,7	138,7
Austria	53,0	54,2	54,3	56,2	56,3	54,4	46,8	48,1	48,0	48,0	55,9	56,4	61,2	62,6	65,7	66,6	68,9	72,0	75,5
Poland	137,5	142,2	153,6	164,4	139,0	143,0	158,7	166,4	162,4	163,7	179,2	187,0	182,0	191,5	175,5	183,2	170,2	181,9	191,0
Portugal	29,3	29,6	35,0	35,8	16,9	16,4	13,6	13,3	13,4	13,2	14,4	14,6	14,7	15,2	15,9	16,4	16,6	17,5	18,6
Romania	369,3	386,8	344,4	369,7	189,1	178,6	201,4	210,5	249,4	249,9	176,6	182,3	177,6	192,3	203,0	210,8	141,4	149,7	156,8
Slovenia	5,8	6,0	6,0	6,5	5,0	4,7	6,0	6,0	4,5	4,5	4,7	4,8	5,5	5,7	8,2	8,5	7,5	8,1	8,6
Slovakia	10,7	11,3	14,5	16,0	11,5	10,9	9,4	9,6	8,4	8,4	8,9	9,3	10,6	11,0	12,4	12,7	12,8	13,3	13,7
Finland	69,7	71,7	72,2	76,0	81,8	75,3	104,3	107,0	91,8	91,0	96,0	96,5	122,9	126,7	128,3	129,8	116,1	119,8	121,7
Sweden	91,8	94,4	95,0	98,3	86,2	82,7	117,6	121,4	156,3	158,2	167,0	174,5	141,6	145,3	138,7	141,4	151,8	161,2	165,7

Note: Eurostat data in black figures; ETC CE estimates in blue figures.

Finally, it is important to point out the data availability issue. Indeed, when estimating odd years and nowcasting an additional year, 'not available' data per country and per industry both in the waste generation and predictor datasets may hinder the whole process. During the implementation phase the ETC CE has checked data availability at country level and has discussed possible options for developing the nowcasts for individual EU-countries with the EEA. This will help in yielding an overview for which Member State nowcasts can be produced in a statistically and methodologically robust manner, which data gaps exist, and how these gaps might be overcome.

2.4.2 Suggested implementation of the approach

The implementation of the approach described above has been developed within an Excel tool. This tool applies the annual change rate to gap fill odd years and five models to nowcast waste generation up to the year 2022.

A second approach (implemented in a second version of the tool) is also proposed for gap filling and nowcasting waste generation. This second approach applies to waste generation by economic activities and by households the annual change rate of their relevant drivers (i.e. GDP and Final consumption expenditure of households) both for gap filling and for nowcasting.

The second version of the tool has been developed for ease of use by EEA, as the first version would need to fully exploit the Excel features such as macro and visual basic.

The two versions of the tool provide differences in the results for the year 2022 only, as for gap filling odd years and nowcasting the two approaches use the same methodology, i.e., annual change rate of predictors. In addition, for the year 2022 results show very small differences between the two approaches, at least at the EU level, as presented in Table 2.7.

Table 2.7 EU results for year 2022 of estimation approach 1 (regression models) and approach 2 (annual change rate of predictors).

	Approach 1	Approach 2	Differences
	Mt	*Mt*	*%*
All industries	2,136.4	2,129.5	- 0.32
Households	219.7	221.6	0.84
Total waste generation	2,356.1	2,351.1	- 0.21

Therefore, for practicality reasons it is suggested to use the **second approach** (i.e., annual change rate of predictors) when carrying out nowcasts for this indicator.

2.5 Diversion of waste from landfills

Landfill diversion (waste sent to landfill as a proportion of waste generated)
The EEA indicator 'Diversion of waste from landfill' (total waste and municipal waste) comprises both the overall and municipal waste (MW) landfill rate[24]. The methodology suggested by the ETC CE for gap filling

[24] The reader should be aware that waste statistics are not suited for the calculation of a recycling rate as generation and treatment have different scope (treatment data provide information on the amounts of waste that are managed in Member States, no matter in which country the waste is generated). Waste policy targets often use nationally generated waste as denominator, for example recycling rates and landfill rates. To calculate the treatment rate of the nationally generated wastes, it is necessary to have the waste generation linked with the waste treatment regardless of the country where wastes are treated. Hence, knowledge of treatment of nationally generated waste, and consequently imports and exports of

and nowcasting the overall and MW rates is largely based on the annual change rate of relevant variables that drive numerators' and denominators' changes. This methodology is implemented in this report at country level and the EU total is calculated as sum of Member States' estimates.

2.5.1 Nowcasting methodology

Overall landfill rate

This rate is calculated as

Disposal of waste in landfills over Total waste generation
(excluding major mineral waste)

where the denominator stems from Eurostat's dataset '*Generation of waste by waste category, hazardousness and NACE Rev. 2 activity* - env_wasgen', the numerator from Eurostat's '*Treatment of waste by waste category, hazardousness and waste management operations* - env_wastrt'.

The numerator is gap filled and nowcasted as follows:

- odd years are interpolated as in Eurostat's dataset '*Management of waste by waste management operations and type of material - Sankey diagram data* – env_wassd';
- estimates for year 2021 are based on the 2018-2021 change rate of data in the dataset env_wassd, setting as waste management operation_'disposal-landfill - DSP_L';
- estimates for year 2022 are based on the 2021 per capita level.

Denominator is gap filled and nowcasted as follows:

- odd years are based on the annual change rate of total waste generation which has been nowcasted within the indicator waste generation.

Results of gap filling and nowcasting the overall landfill rate are shown in Table 2.8 (Eurostat data in black figures; ETC CE estimates in blue figures).

waste and its treatment is essential. Eurostat has been striving to improve waste statistics since the 2021 Waste statistics Working Group.

Table 2.8 Overall landfill rate for the EU-27 and Member States, 2010-2022*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
European Union	22,8	22,6	23,3	23,1	22,4	20,6	19,3	19,2	19,5	16,9	15,8	15,9	15,2
Belgium	5,6	5,0	5,7	5,2	4,2	4,5	4,4	4,8	5,1	4,2	3,3	3,4	3,3
Bulgaria	38,6	65,7	78,8	78,1	76,6	64,9	57,1	57,3	50,2	36,8	30,8	37,0	33,7
Czechia	28,3	25,5	23,0	22,1	22,7	21,8	21,3	21,3	18,3	18,8	21,6	18,0	17,9
Denmark	4,7	4,2	4,1	3,4	2,6	2,1	1,8	1,3	0,8	0,8	0,9	0,4	0,4
Germany	7,9	8,2	8,9	9,8	10,2	10,1	10,1	9,7	9,8	8,8	8,2	9,4	9,3
Estonia	72,1	64,7	67,2	72,3	72,2	71,9	78,8	78,3	79,7	60,7	70,9	90,1	92,4
Ireland	15,6	13,9	19,1	14,7	10,9	10,5	13,7	10,3	9,2	10,0	12,3	6,9	6,5
Greece	73,4	83,1	75,4	71,3	68,5	50,9	48,6	51,9	51,9	40,4	36,8	46,1	42,8
Spain	41,3	39,9	36,3	38,8	38,9	34,3	31,1	32,0	33,2	29,6	29,0	20,4	19,5
France	22,4	21,3	20,9	20,4	20,8	19,6	18,5	19,7	20,6	19,4	19,6	16,6	16,2
Croatia	45,8	46,3	50,1	50,1	46,6	45,7	40,1	38,0	36,1	31,9	27,3	26,2	24,1
Italy	20,9	19,9	18,7	17,8	15,5	14,9	14,2	13,6	13,1	11,8	10,8	11,0	10,5
Cyprus	62,3	60,1	75,7	78,9	73,4	74,1	71,7	70,3	68,2	57,3	45,3	53,6	51,3
Latvia	45,7	43,1	30,0	28,4	26,7	21,6	24,6	26,3	32,2	33,9	20,0	10,4	10,0
Lithuania	36,9	32,7	32,9	29,2	25,1	18,6	12,1	10,9	9,5	7,8	6,3	7,6	7,6
Luxembourg	3,3	3,0	3,2	3,3	5,1	13,7	14,1	8,9	4,2	4,1	4,2	8,5	8,6
Hungary	47,2	48,3	52,3	46,8	40,1	36,9	39,7	36,6	37,5	36,0	36,2	25,8	24,4
Malta	68,4	66,4	55,9	54,4	56,4	52,3	40,7	39,9	52,0	48,8	55,4	57,2	54,6
Netherlands	1,9	2,3	2,8	2,6	2,5	2,5	2,6	2,7	2,9	2,7	2,6	2,2	2,1
Austria	7,5	6,8	7,1	8,6	9,4	8,6	7,6	8,5	9,6	8,5	7,8	10,0	9,6
Poland	26,9	26,7	27,5	28,1	27,4	25,7	24,8	22,9	23,0	17,8	15,5	23,9	22,2
Portugal	32,5	32,6	31,2	29,1	25,9	24,9	24,4	25,6	24,8	25,1	26,5	21,7	20,5
Romania	57,2	54,8	58,1	53,9	55,7	51,8	50,3	47,6	51,9	44,6	47,7	42,3	40,2
Slovenia	22,5	16,4	11,5	9,4	7,5	5,3	3,7	3,8	4,2	4,2	4,9	2,6	2,5
Slovakia	43,5	43,0	43,4	40,5	40,5	42,2	38,1	35,4	32,3	28,7	29,3	31,4	30,6
Finland	13,9	11,7	11,5	10,2	13,4	11,0	8,4	7,0	6,1	5,7	6,3	7,2	7,1
Sweden	6,9	6,8	7,2	7,2	7,3	6,9	6,2	6,2	6,4	5,4	4,8	6,6	6,4

Note: Eurostat data in black figures; ETC CE estimates in blue figures

Municipal waste landfill rate

The municipal waste landfill rate is calculated as

percentage of municipal waste treated that is landfilled.

Eurostat's datasets used for calculating this rate is '*Municipal waste by waste management operations -* env_wasmun'.

The numerator (municipal waste in the waste management operation 'landfill and other') is gap filled and nowcasted as follows:

- Estimates are based on the annual change rate of waste landfilled which has been nowcasted within the overall landfill rate.

The denominator (municipal waste treated) is gap filled and nowcasted as follows:

- Estimates are based on the annual change rate of waste generation by households which has been nowcasted within the indicator waste generation.

Results of gap filling and nowcasting the overall landfill rate are shown in Table 2.9 (Eurostat data in black figures; ETC CE estimates in blue figures).

Table 2.9 Municipal waste landfill rate for EU Member States, 2010-2022*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Belgium	1,7	0,9	0,7	0,9	1,0	0,9	0,8	0,9	1,0	0,9	0,5	0,5	0,4
Bulgaria	75,2	72,4	73,4	69,7	73,8	67,4	64,3	62,0	61,2	62,0	53,2	29,4	26,4
Czechia	67,9	64,8	56,5	56,2	56,0	52,6	50,0	47,6	48,3	47,9	47,2	45,4	46,5
Denmark	2,0	2,6	2,2	1,7	1,4	1,3	1,2	1,0	1,1	0,9	0,9	1,1	1,1
Germany	0,4	0,5	0,2	1,4	1,3	1,3	1,0	0,9	0,8	0,8	0,8	1,4	1,3
Estonia	78,5	72,0	52,2	15,8	7,5	8,5	11,3	20,1	22,8	18,6	17,0	19,9	19,6
Ireland	57,1	52,5	42,1	32,5	21,7	24,7	26,2	22,9	14,6	15,5	16,3	9,6	9,0
Greece	82,9	82,0	82,5	83,7	84,1	83,9	82,3	80,1	78,4	77,7	59,5	75,9	69,5
Spain	62,2	63,0	60,6	55,7	57,7	57,3	54,1	51,2	53,6	51,1	49,4	51,9	50,0
France	29,1	28,0	26,9	25,8	24,8	23,7	21,5	28,7	26,6	26,5	25,7	23,4	22,9
Croatia	95,8	91,6	84,8	84,6	82,8	81,6	78,4	75,4	72,3	66,2	67,1	64,8	60,2
Italy	49,2	44,1	40,7	38,2	33,9	29,0	27,1	25,7	23,6	22,8	22,1	21,0	20,0
Cyprus	88,8	88,3	86,5	85,4	83,3	82,5	79,8	82,8	80,0	79,0	78,8	77,8	73,2
Latvia	90,7	88,4	83,9	72,9	71,3	66,9	70,0	70,3	68,3	56,4	55,5	52,5	48,5
Lithuania	94,4	79,0	75,7	64,0	60,0	54,7	31,3	33,0	27,4	24,5	18,4	16,0	16,1
Luxembourg	16,0	14,5	14,5	14,3	14,4	7,5	4,6	4,4	4,3	4,5	3,8	3,9	3,9
Hungary	70,4	67,3	65,4	64,6	58,7	53,7	50,6	48,6	49,4	50,6	54,0	51,0	47,5
Malta	90,8	83,2	84,4	86,4	86,9	90,4	85,7	87,3	88,9	90,9	88,4	82,8	77,0
Netherlands	1,5	1,6	1,5	1,5	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,3
Austria	3,3	5,0	4,4	4,2	4,2	3,0	2,7	2,1	2,2	2,1	1,8	2,0	2,0
Poland	80,0	85,5	84,4	73,9	58,4	54,3	45,7	41,8	41,6	43,0	39,8	38,7	36,6
Portugal	62,0	58,9	54,4	50,5	49,0	48,4	47,4	48,8	50,5	49,8	54,2	49,5	47,0
Romania	85,3	86,1	80,4	82,0	82,0	82,1	75,0	79,9	82,6	82,3	80,8	81,5	76,9
Slovenia	70,9	60,4	49,5	42,6	39,2	24,2	9,9	12,8	12,2	12,4	8,5	7,7	7,1
Slovakia	79,5	77,1	75,6	76,7	75,8	72,8	65,9	60,6	55,4	52,2	46,3	41,3	39,0
Finland	45,1	40,2	32,9	25,1	17,4	11,5	3,3	0,9	0,7	1,0	0,5	0,4	0,4
Sweden	0,9	0,8	0,6	0,6	0,6	0,8	0,6	0,4	0,7	0,8	0,5	0,6	0,5

Note: **Eurostat data in black figures; ETC CE estimates in blue figures**

2.6 Waste recycling

Waste recycling in Europe

The section on waste recycling comprises gap filling and nowcasting the recycling rates for different waste streams: (1) total waste, (2) municipal waste, (3) packaging waste, (4) electrical, and (5) electronic waste.

The methodology adopted to gap fill and nowcast these waste streams is based on the annual change rate of relevant variables that affect numerators and denominators of the rates. This methodology is implemented at country level and the EU total is calculated as sum of Member States' estimates.

2.6.1 Overall recycling rate

The overall recycling rate is calculated (according to EEA[25]) as

recycling over total waste generation
(excluding major mineral waste)

Source of numerator is Eurostat's dataset '*Treatment of waste by waste category, hazardousness and waste management operations* – env_wastrt'. Source of denominator is total waste generation excluding

25 Indeed, Eurostat calculates this rate as recycling over total waste treated (excl. major mineral waste). See metadata of the indicator "Recycling rate of all waste excluding major mineral waste (cei_wm010)"

major mineral wastes which has been gap filled and nowcasted up to year 2022 within the 'Overall landfill rate'. Therefore, only numerator needs to be gap filled and nowcasted.

Numerator (recycling, excluding major mineral waste) is gap filled and nowcasted as follows:

- odd years are based on the annual change rate of value added of the circular economy (CE) sector[26] building on Eurostat dataset '*Private investment and gross added value related to circular economy sectors -* cei_cie012';
- estimates for year 2022 are based on a two-step process. First, the CE sector's value added for the year 2022 is calculated based on the last three years' average of the ratio "CE sector / GDP"; second, the annual change rate 2021-2022 is applied to calculate the recycling value for 2022.

Results of gap filling and nowcasting the overall recycling rate are showed in Table 2.10 (Eurostat data in black figures; ETC CE estimates in blue figures).

Table 2.10 Overall recycling rate for the EU-27 and Member States, 2010-2022*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
European Union	42,9	43,2	45,0	46,4	46,9	47,9	45,8	47,4	46,4	48,8	46,1	44,8	48,8
Belgium	57,9	60,8	95,1	100,7	90,7	90,9	82,1	83,7	89,6	99,0	87,8	84,5	92,5
Bulgaria	10,4	10,2	9,5	9,3	14,4	15,1	21,0	24,8	14,6	15,8	37,6	36,5	46,0
Czechia	32,9	34,6	37,4	36,9	42,5	43,9	42,9	43,9	41,9	44,1	39,2	39,2	46,3
Denmark	42,5	45,7	35,8	36,3	32,3	32,7	40,6	38,4	33,0	30,9	37,0	36,1	39,5
Germany	48,4	47,7	46,8	47,9	46,9	51,2	47,2	51,0	47,5	49,2	48,5	48,9	52,5
Estonia	16,0	17,3	18,9	19,1	14,0	13,8	7,7	8,4	9,1	8,6	11,7	11,2	13,7
Ireland	7,0	6,9	7,5	7,5	13,2	11,1	11,5	10,9	14,6	14,4	14,2	12,7	14,9
Greece	20,1	18,6	12,3	9,0	9,5	9,3	20,7	23,1	26,7	30,0	25,6	24,4	30,9
Spain	45,8	45,6	42,5	49,6	45,0	45,3	37,4	38,5	39,7	42,6	37,1	36,5	38,4
France	36,5	36,4	35,2	35,2	38,7	38,6	41,6	45,5	39,4	39,2	35,6	33,9	35,7
Croatia	12,9	12,0	28,2	30,3	43,1	45,6	39,9	41,2	42,9	45,3	44,2	41,5	48,3
Italy	47,6	46,3	52,7	55,7	53,0	54,0	53,4	50,2	54,7	61,9	56,2	53,8	56,7
Cyprus	35,6	33,2	9,6	9,8	12,5	12,9	13,5	14,4	15,4	16,0	23,0	23,0	25,7
Latvia	12,6	12,2	34,4	33,0	49,0	48,1	82,9	85,0	46,1	48,8	43,0	42,1	51,9
Lithuania	25,1	29,6	19,6	19,6	21,4	22,3	29,4	32,6	24,2	26,6	28,6	28,9	35,8
Luxembourg	277,6	277,9	256,1	267,9	296,3	327,7	212,5	235,1	228,4	253,4	217,4	218,0	248,6
Hungary	25,2	21,5	25,1	21,6	28,0	28,4	30,8	36,2	38,0	28,9	49,8	48,7	53,5
Malta	0,0	0,0	1,2	1,2	0,9	0,9	0,5	0,6	0,5	0,6	0,7	0,7	0,8
Netherlands	63,0	62,4	67,9	64,7	67,1	67,3	67,0	68,0	68,2	70,4	66,6	64,0	71,6
Austria	42,5	42,7	57,9	60,0	57,0	57,0	64,0	67,7	60,0	60,0	59,1	57,9	60,5
Poland	54,5	57,8	50,3	52,6	60,3	58,9	46,6	48,8	49,9	52,6	33,9	32,7	37,4
Portugal	31,2	30,5	31,9	31,0	37,4	40,5	27,0	28,1	31,2	29,7	29,8	29,7	31,8
Romania	23,4	24,7	27,5	27,4	25,8	26,7	27,3	29,1	22,7	24,0	27,3	26,6	32,1
Slovenia	47,2	48,1	75,6	75,9	67,9	69,2	74,4	77,0	80,7	90,5	76,6	73,4	82,7
Slovakia	30,6	30,0	32,6	30,9	31,5	33,7	35,6	37,8	33,7	33,9	45,2	44,3	49,8
Finland	29,0	28,2	38,9	36,9	29,2	30,2	23,0	24,3	27,0	25,0	37,2	36,9	40,7
Sweden	37,4	41,6	39,6	44,1	40,9	40,1	37,2	38,1	37,7	36,6	34,9	33,7	35,1

Note: Eurostat data in black figures; ETC CE estimates in blue figures

Suggested implementation of the approach

It is suggested to use the proposed methodology (annual change rate in relevant predictors for numerator and denominator) according to Eurostat's definition of recycling rate of all waste excluding major mineral waste (CEI_WM010), where the indicator is calculated as recycled waste over total waste treated excluding major mineral wastes.

26 The value added of the CE sectors is assumed as the driver of the numerator of the rate (i.e. recycling).

In this case the denominator to be estimated is total waste treated (excluding major mineral waste). The annual change rate of total waste generated (excluding major mineral waste) is applied for gap filling and nowcasting total waste treated.

Results of the overall recycling rate for EU and Member States from 2010 to 2022 using Eurostat's approach to calculate the rate are provided in Table 2.11.

Table 2.11 Overall recycling rate for the EU-27 and Member States, 2010-2022 (using Eurostat's approach to calculate the rate)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
European Union	50,9	51,3	51,2	52,8	53,1	54,2	54,1	56,1	54,5	57,3	56,4	54,9	59,9
Belgium	71,8	75,3	76,6	81,1	78,5	78,6	77,8	79,3	79,4	87,7	86,1	82,9	90,7
Bulgaria	20,3	20,0	10,6	10,4	15,6	16,4	25,9	30,5	21,5	23,2	51,5	50,0	63,1
Czechia	41,5	43,6	49,1	48,4	50,8	52,5	52,1	53,4	55,5	58,4	52,8	52,8	62,3
Denmark	55,6	59,8	48,1	48,8	46,7	47,2	50,7	48,1	46,3	43,4	50,2	48,9	53,6
Germany	52,9	52,2	51,4	52,6	51,5	56,2	51,7	55,9	51,9	53,8	53,8	54,2	58,2
Estonia	17,6	19,0	21,0	21,1	15,5	15,2	8,3	9,0	9,9	9,3	13,5	12,9	15,8
Ireland	26,1	25,6	20,5	20,4	33,8	28,3	31,0	29,2	33,2	32,7	32,6	29,1	34,2
Greece	20,1	18,6	12,8	9,4	11,2	10,9	25,3	28,1	29,6	33,3	37,9	36,0	45,6
Spain	50,0	49,8	50,4	58,8	50,4	50,7	50,4	51,9	50,8	54,5	51,9	51,1	53,7
France	45,6	45,5	46,4	46,3	48,1	48,0	50,2	54,8	47,9	47,6	43,1	41,0	43,2
Croatia	16,9	15,7	35,3	38,0	47,0	49,7	49,3	50,8	52,7	55,6	57,1	53,6	62,4
Italy	61,8	60,2	66,2	69,9	68,6	70,0	70,2	66,0	69,6	78,8	74,9	71,7	75,6
Cyprus	35,7	33,3	10,6	10,8	13,8	14,2	14,1	15,1	15,4	16,0	26,1	26,1	29,1
Latvia	19,8	19,1	45,5	43,7	54,0	52,9	71,2	73,0	48,4	51,2	60,1	58,9	72,6
Lithuania	36,7	43,3	34,5	34,5	40,8	42,3	59,0	65,5	58,3	64,0	61,3	61,9	76,6
Luxembourg	95,4	95,5	94,0	98,3	91,3	100,9	87,5	96,8	90,7	100,6	89,3	89,6	102,1
Hungary	31,3	26,7	29,0	24,9	35,4	35,8	38,2	44,9	44,0	33,4	50,6	49,5	54,3
Malta	0,0	0,0	2,0	2,1	1,6	1,6	1,2	1,4	1,0	1,1	1,3	1,2	1,3
Netherlands	72,7	72,0	71,0	67,6	69,7	69,9	69,2	70,2	71,2	73,6	71,7	68,9	77,1
Austria	61,6	61,9	65,9	68,2	63,8	63,8	68,2	72,1	65,6	65,5	66,8	65,4	68,4
Poland	57,4	60,9	53,9	56,4	59,6	58,3	55,5	58,0	58,9	62,1	49,5	47,7	54,6
Portugal	41,3	40,4	43,2	42,0	49,9	54,0	43,6	45,4	47,9	45,5	45,5	45,3	48,6
Romania	25,8	27,2	28,5	28,4	27,2	28,1	29,5	31,4	26,0	27,5	31,6	30,9	37,3
Slovenia	58,4	59,5	77,0	77,3	80,3	81,9	85,5	88,5	86,8	97,3	85,5	82,0	92,3
Slovakia	38,4	37,6	39,6	37,4	40,1	42,9	43,6	46,3	45,6	45,8	54,4	53,3	59,9
Finland	34,1	33,1	38,7	36,7	37,6	38,9	32,8	34,6	34,9	32,3	40,2	39,8	43,9
Sweden	47,4	52,7	47,0	52,4	45,3	44,5	43,1	44,2	43,8	42,5	41,3	39,8	41,5

Source: ETC CE calculations based on Eurostat data.

2.6.2 Other recycling rates

Municipal waste recycling rate

The municipal waste recycling rate is measured as the

share of recycled municipal waste in the total municipal waste generation.

Eurostat's dataset for calculating the rate is '*Municipal waste by waste management operations - env_wasmun*'. In particular, the waste management operations recycling and waste generated are considered for numerator and denominator, respectively.

Numerator (recycling of municipal waste) is gap filled and nowcasted up to year 2022 as follows:

- estimates for the year 2022 are based on the annual change rate of recycling of waste excluding major mineral wastes which has been nowcasted within the 'Overall recycling rate'.

Denominator (municipal waste generation) is gap filled and nowcasted as follows:

- estimates for the year 2022 are based on the annual change rate of waste generation by households which has been nowcasted within the indicator 'waste generation'.

Results of gap filling and nowcasting the municipal waste recycling rate are showed in Table 2.12 (Eurostat data in black figures; ETC CE estimates in blue figures).

Table 2.12 Municipal waste recycling rate for the EU-27 and Member States, 2010-2022*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
European Union	38,0	38,9	40,9	41,5	43,4	44,9	45,9	46,3	46,4	47,2	48,9	48,7	52,1
Belgium	54,8	54,4	53,4	52,8	53,8	53,5	53,5	53,9	54,4	54,7	51,4	55,5	60,4
Bulgaria	24,5	26,2	25,0	28,5	23,1	29,4	31,8	34,6	31,5	34,6	35,2	28,2	35,1
Czechia	15,8	16,9	23,2	24,2	25,4	29,7	33,6	32,1	32,2	33,3	40,5	43,3	52,6
Denmark	42,8	42,4	42,5	43,3	45,4	47,4	48,3	47,6	49,9	51,5	45,0	57,6	65,3
Germany	62,5	63,0	65,2	63,8	65,6	66,7	67,1	67,2	67,1	66,7	70,3	67,8	71,5
Estonia	18,0	23,3	19,1	17,6	31,1	28,3	27,9	28,2	28,0	30,8	28,9	30,3	35,6
Ireland	35,7	36,1	36,6	36,6	39,8	39,3	40,7	40,4	37,7	37,4	40,8	38,3	45,1
Greece	17,1	17,8	17,0	15,8	15,4	15,8	17,2	18,9	20,1	21,0	15,1	14,6	18,3
Spain	29,2	26,7	29,8	32,5	30,8	30,0	33,9	36,1	34,8	38,0	40,5	36,7	38,8
France	36,0	36,8	37,7	38,7	39,7	40,7	39,7	40,2	40,7	41,0	41,7	43,8	46,0
Croatia	4,1	8,3	14,7	14,9	16,4	18,0	21,0	23,6	25,3	30,2	29,5	31,4	36,9
Italy	31,0	35,5	38,4	39,4	41,6	44,3	45,9	47,8	49,8	51,4	51,4	51,9	54,2
Cyprus	10,9	11,0	12,5	13,9	14,8	16,6	16,1	16,0	16,7	16,6	16,6	15,3	16,8
Latvia	9,4	9,7	14,6	25,9	27,0	28,7	25,2	24,8	25,2	41,0	39,7	44,1	52,3
Lithuania	4,9	20,0	23,5	27,8	30,5	33,2	48,0	48,1	52,6	49,7	45,3	44,3	55,4
Luxembourg	46,5	46,4	47,4	46,3	47,7	47,4	49,2	48,9	49,0	48,9	52,8	55,3	62,4
Hungary	19,6	22,0	25,5	26,4	30,5	32,2	34,7	35,0	37,4	35,9	32,0	34,9	37,8
Malta	8,9	15,4	14,8	12,5	11,7	10,9	12,7	11,5	10,4	9,1	10,9	13,6	14,4
Netherlands	49,2	49,1	49,4	49,8	50,9	51,8	53,5	54,6	55,9	56,9	56,9	57,8	63,3
Austria	59,4	56,7	57,7	57,7	56,3	56,9	57,6	57,8	57,7	58,2	62,3	62,5	65,3
Poland	16,3	11,4	12,0	15,1	26,5	32,5	34,8	33,8	34,3	34,1	38,7	40,3	46,8
Portugal	18,7	20,1	26,1	25,8	30,4	29,8	30,9	29,1	29,1	28,9	26,8	30,4	32,8
Romania	12,8	11,7	14,8	13,2	13,1	13,3	13,4	14,0	11,1	11,5	11,9	11,3	13,6
Slovenia	22,4	35,7	42,1	34,8	36,0	54,1	55,5	57,8	58,9	59,2	59,3	60,8	66,3
Slovakia	9,1	10,9	13,4	10,8	10,4	14,9	23,0	29,8	36,3	38,5	45,3	48,9	53,3
Finland	32,8	34,8	33,3	32,5	32,5	40,6	42,1	40,5	42,3	43,5	42,1	39,0	43,0
Sweden	47,8	47,0	46,9	48,2	49,3	47,6	48,4	46,8	45,8	46,6	38,3	39,5	41,6

Note: Eurostat data in black figures; ETC CE estimates in blue figures

Packaging waste recycling rate

The recycling rate of this waste stream is measured as the

share of recycled packaging waste in all generated packaging waste.

Eurostat's dataset for calculating the rate is '*Packaging waste by waste management operations* - env_waspac'. In particular, the waste management operations 'recycling' and 'waste generated' are considered for numerator and denominator, respectively. Please also note that packaging rates are available within Eurostat dataset '*Recycling rate of packaging waste by type of packaging* - cei_wm020' up to year 2021, not for all countries though.

The numerator (packaging waste recycling) is gap filled and nowcasted up to year 2022 as follows:

- estimates for nowcasted as well as gap filled data are based on the annual change rate of recycling of waste excluding major mineral wastes which has been nowcasted within the 'Overall recycling rate', except for the period 2005-2011 for Croatia which is calculated as difference between EU27 and Member States.

Denominator (packaging waste generation) is gap filled and nowcasted as follows:

- nowcasted and gap filled data are based on the annual change rate of recycling of waste generation by households which has been nowcasted within the indicator waste generation, except 2005-2011 data for Croatia which are calculated as difference between EU27 and all MS.

Results of gap filling and nowcasting the packaging waste recycling rate are showed in Table 2.13.

Table 2.13 Packaging waste recycling rate for the EU-27 and Member States, 2010-2022

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
European Union	**64,0**	**64,2**	**65,2**	**65,4**	**66,5**	**66,6**	**67,6**	**67,5**	**65,6**	**64,8**	**64,0**	**64,0**	**64,0**
Belgium	79,8	80,2	80,3	78,7	81,3	81,5	81,9	83,8	85,3	83,5	79,7	80,4	83,5
Bulgaria	61,6	65,1	66,5	65,7	62,0	64,1	63,8	65,6	60,4	61,2	172,1	165,2	205,7
Czechia	70,0	69,7	69,9	69,9	73,0	74,3	75,3	72,3	69,6	71,2	67,9	69,1	81,9
Denmark	84,0	54,3	61,6	69,8	69,8	73,9	79,0	71,5	70,1	70,4	64,0	61,6	70,0
Germany	72,7	71,8	71,3	71,8	71,4	69,3	70,7	69,9	68,5	64,0	68,1	67,9	73,4
Estonia	56,1	62,9	61,3	58,4	60,3	59,0	56,0	53,5	60,4	66,2	71,4	70,4	81,6
Ireland	66,2	70,9	74,0	70,2	68,3	67,5	67,0	65,6	63,9	62,5	62,4	58,1	68,2
Greece	58,7	62,1	58,6	52,4	53,8	60,3	66,1	68,6	63,6	60,1	43,2	41,9	52,2
Spain	61,9	63,9	65,5	66,6	68,7	68,4	70,3	68,5	68,8	69,6	68,3	70,1	66,4
France	61,1	61,3	64,9	66,4	65,2	65,5	66,0	68,1	63,5	65,6	60,3	61,8	58,4
Croatia	57,2	57,2	59,7	58,8	52,7	60,1	54,7	53,3	58,4	48,9	54,2	50,8	61,1
Italy	64,4	64,5	66,6	66,7	65,4	66,8	66,9	67,1	68,3	69,6	72,8	72,9	70,9
Cyprus	50,0	52,0	55,3	56,6	58,7	59,8	64,6	66,2	70,2	66,8	59,9	63,5	65,7
Latvia	48,9	50,9	51,1	51,0	54,9	53,9	57,7	58,7	55,8	62,4	61,4	61,0	69,3
Lithuania	60,4	62,2	62,2	53,5	57,7	59,8	69,5	61,8	60,7	61,9	61,8	61,4	76,8
Luxembourg	66,0	66,0	62,5	62,8	66,0	70,0	70,3	69,7	70,9	71,5	71,9	73,7	78,7
Hungary	58,7	59,3	48,5	49,2	48,4	50,1	49,7	49,7	46,1	47,0	52,4	47,8	51,8
Malta	28,5	42,3	46,6	38,1	41,1	37,1	39,7	35,6	35,7	33,7	40,0	38,4	42,3
Netherlands	73,9	71,9	69,3	70,4	70,5	71,7	72,6	78,1	79,4	80,7	76,5	76,8	79,9
Austria	66,6	65,8	65,9	66,6	66,6	67,1	66,8	65,6	65,5	65,4	63,7	65,8	65,4
Poland	38,9	41,2	41,4	36,1	55,4	57,6	58,0	56,7	58,7	55,5	23,4	22,7	26,4
Portugal	55,5	58,4	56,9	61,5	61,0	57,1	60,9	55,3	57,9	62,8	59,5	63,1	64,2
Romania	43,4	50,0	56,8	52,8	54,8	55,9	60,4	60,4	57,9	44,6	39,9	38,0	45,5
Slovenia	61,0	63,6	66,9	69,0	70,4	67,0	69,4	70,1	68,0	67,1	67,9	55,1	70,2
Slovakia	45,7	62,4	68,1	65,9	65,4	64,3	65,8	65,7	66,6	67,5	70,8	70,6	76,8
Finland	55,4	58,7	59,3	58,0	57,4	60,9	64,7	65,2	70,2	70,6	73,2	72,5	63,5
Sweden	69,2	71,5	69,6	71,9	70,5	71,8	68,2	71,7	65,0	63,6	60,9	59,6	60,8

Source: ETC CE calculations based on Eurostat data.

Waste electrical and electronic equipment recycling rate

The recycling rate of waste electrical and electronic equipment (WEEE) is measured as the

WEEE that enters the recycling/preparing for re-use facility over all separately collected WEEE

according to Article 11(2) of the WEEE Directive 2012/19/EU. Eurostat's dataset for calculating the rate is '*Waste electrical and electronic equipment (WEEE) by waste management operations - open scope, 6 product categories (from 2018 onwards)* - env_waseleeos'. In particular, the waste management operations 'recycling' and 'waste generated' are considered for numerator and denominator, respectively. Please also note that packaging rates are available within the Eurostat dataset '*Recycling rate of packaging waste by type of packaging* - cei_wm020' up to the year 2021 (but not for all countries).

Numerator (WEEE recycling and preparing for reuse) is gap filled and nowcasted up to year 2022 as follows:

- estimates for nowcasted and gap filled data are based on the annual change rate of recycling of waste excluding major mineral wastes nowcasted within the 'Overall recycling rate';

Denominator (WEEE collected) is gap filled and nowcasted as follows:

- it is assumed that the variation in WEEE collected amounts reflects annual changes in EEE consumption level of some electrical and electronic equipment, i.e.: household appliances; telephone and telefax equipment; audio-visual, photographic and information processing equipment. These consumption items are derived from Eurostat's dataset '*Final consumption expenditure of households by consumption purpose* - nama_10_co3_p3'.

Results of gap filling and nowcasting the WEEE recycling rate are shown in Table 2.14.

Table 2.14 WEEE recycling rate for the EU-27 and Member States, 2010-2022

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
European Union	**81,8**	**84,7**	**81,4**	**82,7**	**81,9**	**80,8**	**84,2**	**84,0**	**81,7**	**81,3**	**83,2**	**81,3**	**86,4**
Belgium	80,2	77,7	78,4	79,1	76,7	77,4	72,5	75,1	72,5	70,8	73,5	72,2	80,4
Bulgaria	78,4	82,3	84,0	83,5	84,9	85,6	81,5	83,7	81,0	83,0	83,6	89,0	106,9
Czechia	86,7	86,8	80,6	91,1	85,5	82,5	90,0	86,9	84,7	92,6	88,8	94,5	111,4
Denmark	83,5	92,0	84,4	82,6	83,0	84,2	86,4	85,8	80,7	83,7	84,1	79,9	95,9
Germany	82,8	83,9	83,5	82,8	84,2	79,3	86,7	85,8	85,6	85,4	86,7	86,1	93,6
Estonia	82,7	69,5	80,4	66,0	85,1	86,7	86,7	85,7	85,7	80,6	81,6	81,6	89,6
Ireland	80,3	82,1	83,4	83,3	83,7	83,2	85,1	83,8	82,9	84,9	84,8	83,4	107,6
Greece	98,0	90,9	90,2	90,6	84,0	89,6	85,4	78,8	80,7	79,0	84,6	80,9	86,5
Spain	67,4	80,3	84,5	82,0	76,9	75,7	87,8	83,1	86,2	79,7	85,8	73,0	68,5
France	77,4	77,9	76,7	78,7	80,8	81,9	81,9	81,9	74,2	76,5	79,8	77,2	84,1
Croatia	77,3	84,5	92,3	97,4	95,7	92,5	96,3	95,2	91,2	92,3	94,9	92,0	95,8
Italy	86,2	93,1	80,0	88,0	82,3	85,7	86,0	88,9	84,3	82,2	86,4	87,1	80,8
Cyprus	71,6	78,9	86,6	80,3	89,4	91,0	87,8	78,3	90,6	81,4	90,9	81,6	87,8
Latvia	84,6	81,5	83,6	90,3	90,3	82,2	88,5	80,8	81,4	83,0	83,5	83,5	104,8
Lithuania	72,4	70,3	68,7	69,5	75,7	80,7	82,3	82,2	81,8	82,7	82,0	84,3	98,7
Luxembourg	85,7	86,0	86,8	87,6	88,0	86,9	87,4	89,1	88,0	88,5	87,9	89,0	95,8
Hungary	82,3	87,7	81,5	87,7	87,0	83,3	84,0	84,2	83,5	83,7	81,9	79,6	83,9
Malta	56,4	122,8	71,7	97,5	107,1	65,1	103,4	72,1	73,6	59,8	58,3	58,3	51,2
Netherlands	79,9	81,8	83,0	83,1	82,4	82,1	80,9	81,6	75,6	69,6	74,0	71,1	80,5
Austria	79,9	81,5	80,0	79,0	79,6	81,1	81,8	80,2	79,8	81,9	82,0	81,6	85,4
Poland	78,4	90,0	76,3	75,6	73,5	69,7	82,2	82,7	87,6	82,4	85,9	85,9	92,5
Portugal	85,0	83,0	86,6	86,6	76,9	78,0	82,1	80,9	73,0	78,5	62,9	51,7	52,2
Romania	84,7	85,1	84,3	86,7	87,3	66,0	74,0	83,4	83,1	81,5	76,0	76,0	76,4
Slovenia	78,5	75,1	79,7	51,0	81,6	86,2	75,8	86,9	84,6	87,8	85,6	87,1	103,4
Slovakia	87,1	86,6	87,8	85,1	90,7	86,7	89,4	88,6	88,9	91,2	92,6	92,5	99,0
Finland	88,5	89,1	89,4	87,9	87,8	92,5	88,9	90,0	89,7	87,8	90,8	88,1	106,1
Sweden	83,9	83,6	84,3	83,7	84,1	83,6	83,4	83,5	83,3	86,6	74,1	76,3	77,8

Source: ETC CE calculations based on Eurostat data.

Suggested implementation of the approach

One excel-based calculation tool for each of the recycling rates – overall, municipal waste, packaging and WEEE rates – is developed within the project. The calculation routine follows the nowcasting approaches discussed in previous sections and allows for automated estimates of results for the nowcasted indicator with new data becoming available.

2.7 Circular materials use rate (CMUR)

The CMUR measures the share of material recovered and fed back into the economy in overall material use:

$$\text{circular material use rate (CMUR)} = \frac{\text{circular use of materials}}{\text{overall use of materials}}$$

The circular use of materials (numerator) is approximated by the amount of waste recycled in domestic recovery plants, corrected by imports and exports. The overall use of material (denominator) is measured by domestic material consumption (DMC), and additionally the circular use of materials is included to ensure that the rate ranges between 0 and 1. Domestic material consumption is the total amount of material used directly in an economy as defined in economy-wide material flow accounts[27].

Data sources that define both the numerator and the denominator of the CMUR are identified as the best proxies among official statistics of the European Statistical System. Data are available for the whole EU economy and by material category – biomass[28], metal ores[29], non-metallic minerals[30] and fossil energy carriers/materials[31] (Eurostat, 2018a).

The CMUR components are DMC, waste recycling, notably recycling, RCV_R[32], and international trade in waste bound for recovery (IMP_W[32] and EXP_W[32]). The rate stems from the ratio between circular use of materials (U) and overall material use (DMC + U).

The formula for the CMUR is:

$$CMU = \frac{U}{DMC + U} = \frac{(RCV\_R - IMP_w + EXP_w)}{DMC + (RCV\_R - IMP_w + EXP_w)}$$

The CMUR is developed making use of different European statistics, all of them provided by Eurostat. The components of the CMUR by material category are based on the following.

- The **DMC** component is directly available, and provided in the material flow categories, from the economy-wide material flow accounts and its early estimates (Eurostat, 2022b).
- The **U** component, the circular use of materials, is calculated based on the amount of waste recycled in domestic recovery plants, RCV_R, derived from waste statistics[33], minus imported waste destined for recovery (IMP_W) and plus exported waste destined for recovery abroad (EXP_W)[34].
  - The component for recycling, **RCV_R**, is derived from the treatment of waste by waste category, hazardousness and waste operations dataset[35] (Eurostat, 2023c). The statistic is provided through a waste category classification, requiring a conversion to the

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27 Eurostat metadata of material flow accounts of which the DMC is part: env_ac_mfa.

28 Biomass "*records material flows from the environment to the economy related to the human appropriation of cultivated and non-cultivated biomass. While the latter, for example, wild fish catch, hunting and gathering, logging from natural forests, can be measured straightforwardly at the boundary between environment and economy, the former cannot and by convention the so-called harvest approach is introduced. Amounts harvested from cultivated biological resources are available from agriculture and forestry harvest statistics.*" (Eurostat, 2018b)

29 Metal ores "*records material flows from the environment to the economy related to the mining of metallic minerals performed through underground or open-cast extraction, seabed mining, etc*". (Eurostat, 2018b)

30 Non-metallic minerals "*records material flows from the environment to the economy related to mining and quarrying of mineral material other than metals and fossil energy carriers such as stone, sand, clay, salt, etc. It refers not only to the extraction from a mine or quarry, but also the dredging of alluvial deposits, rock crushing and the use of salt marshes.*" (Eurostat, 2018b)

31 Fossil energy materials/carriers extraction "*records material flows from the environment to the economy related to extraction of solid, liquid and gaseous fossil mineral fuels through underground or open-cast mining, and the operation of crude oil and natural gas fields. Extraction of oil shale and sands is included*". (Eurostat, 2018b)

32 RCV_R: the amount of waste recycled in domestic recovery plants. Waste recycled in domestic recovery plants comprises the recovery operations R2 to R11 as defined in the Waste Framework Directive 2008/98/EC.
IMP_w: the amount of imported waste destined for recycling.
EXP_w: the amount of exported waste destined for recycling abroad.

33 Eurostat metadata on waste generation and treatment: env_wasgt.

34 See the Eurostat manual: Circular material use rate — Calculation method — 2018 edition

35 This statistic is collected on the basis of the Waste Statistics Regulation (EC) No 2150/2002.

material categories to derive the RCV_R at a material category level. The conversion factors from waste categories to material categories are provided by Eurostat[36]. The data is only available for every even year[37].

- The components **IMP_W** and **EXP_W** are approximated from the international trade in goods statistics (Eurostat, 2023a)[38]. A list of combined nomenclature (CN) codes used to approximate the imports and exports of waste destined for recycling is provided by Eurostat[39], together with their allocation to the four material categories.

The underlying datasets determining the EU-27 total, and MS-level final demand are described in Table 2.15 below.

Table 2.15 Eurostat statistics used to calculate the CMUR and their update frequency

Name	Online data code	Currently available data	Dissemination of data
Circular material use rate (**CMUR** indicator)	env_ac_cur	2010-2021 (last update 24/01/2023; at MS-level)	T+11 months[40] New data points are disseminated within one year after the reference year. One of the data sources used, namely waste statistics, is available only every second year. Eurostat estimates data for the missing odd years. The other data sources necessary are available every year. The missing data are estimated by Eurostat.
Circular material use by material type (**CMUR** indicator by material category)	env_ac_curm	2010-2021 (last update 24/01/2023; only EU-27)	T+11 months
Material flow accounts (**DMC** indicator)	env_ac_mfa	2000-2021 (last update 01/07/2022; at MS-level)	T+6 months
Treatment of waste by waste category, hazardousness and waste management operations (**RCV_R** indicator needing conversion exercise to get to the material category level)	env_wastrt	2010-2020 (last update 13/01/2023; only even years; at MS-level)	T+20 months, updates in T+23, T+27 and T+31
Material flows for circular economy – Sankey diagram data (**IMP_W** and **EXP_W** indicator by material category)	env_ac_sd	2010-2021 (last update 20/02/2023; at MS-level)	T+11 months

2.7.1 Nowcasting methodology

Quantitatively, the most important components of the CMUR are DMC and recycling. The other components, i.e., the waste flows which are imported and exported, are relatively small in absolute

36 WStatR in MFA (europa.eu)

37 A gap filling (interpolation) and nowcasting methodology is developed by Eurostat to allow a yearly estimation of the CMUR.

38 Eurostat metadata on international trade in goods

39 cei_srm030_esmsip_CN-codes.pdf (europa.eu)

40 Following the release calendar from Eurostat, the Material flows for the circular economy (with estimates for 2022) and the CMUR (estimates for 2022) will be published on the 14th of November 2023.

values at EU-level and they cancel each other out so the net trade is negligible. This means that an additional year could be estimated for the EU-27 using the DMC early estimates released by Eurostat at T+6 months and the nowcasted waste recycling (see Section 2.6 following gap filling for odd years and the annual change rate using data for GDP and the CE sector value added).

With DMC and RCV_R available at MS-level and by material categories, the CMUR by material categories could be nowcasted for each MS and for the EU-27. However, the following concerns should be considered:

- New data points on the CMUR are disseminated by Eurostat within one year after the reference year. However, when these underlying datasets are updated, the data on the CMUR doesn't change automatically, but only when the CMUR is updated (approx. once per year). This makes it difficult to replicate the CMUR values. It requires exactly the same version used by Eurostat to calculate the CMUR, although more recent version might be available.
- While at EU-level, waste trade is small compared to overall waste/material flows in the CMUR calculation, this may not always be the case for all individual EU-countries. Hence, a nowcasting of waste trade data at country level (or assuming it stays at the levels of the previous year) might be necessary. This could not be investigated in depth in this project due to time constraints.
- The nowcasting methodology requires input from the early estimate on DMC by Eurostat at T+6 months (released this year on 13 July). Based on the release calendar of Eurostat, the CMUR is published in T+11 months (released this year on 14 November[41]). This is a limited gain of only 3-4 months, but still requires an extensive exercise (especially at MS-level).
- The CMUR is also a very prominent CE indicator for the EC (against the doubling target). Releasing a (possibly different) nowcasted CMUR only a few months before Eurostat is releasing their estimate, might give rise to confusion.

2.7.2 Suggested implementation of the approach

Given the limitations associated with nowcasting the CMUR (see above) and the limited gains of only being able to provide results three to four months prior to Eurostat early estimates (T+11 months), we suggest to rely on the Eurostat early estimates. This also helps to avoid confusion if the EEA nowcasts deviate from Eurostat early estimates (e.g., due to data updates involving different versions of the underlying data (see previous section)).

An alternative option could be to work closely with Eurostat in the future to ensure that the same underlying data versions are used when providing nowcasting estimates a few months in advance to Eurostat early estimates.

Another option could be to follow a more qualitative approach in which the focus is on the changes in the different components of the CMUR (being the DMC and the RCV_R), e.g., in a brief discussion in the text of the EEA indicator website for the CMUR.

41 https://ec.europa.eu/eurostat/news/release-calendar

3 Outlooks

In this chapter we discuss the methodology and the main results of an outlook approach for the six EEA CE indicators up to the year 2035. The methodology developed by the ETC CE is the result of a tradeoff between scientifically robustness and replicability. The outlook exercise does not take the form of scenarios, but instead tries to assess the most likely development for the data underpinning each of the six EEA indicators.

The outlook will also consider the impact of the COVID-19 pandemic as well as the most recent energy crisis due to the Russia-Ukraine conflict. The COVID-pandemic has been a profound shock to the EU, whilst hitting member states' economies to different extents. Overall, lockdowns and restrictions on businesses resulted in a sharp decline of economic activity. Restrictions on international trade, factory closures, and transportation slowdown negatively influenced the flow of goods and services, leading to shortages of critical supplies and components in various industries. From an environmental point of view, the shrinking of production and demand also had a temporary effect, e.g., in terms of GHG emission reductions in 2020.

In 2022, geopolitical instability due to the Russian invasion of Ukraine caused energy prices to increase, resulting in a 13 % reduction in energy demand leading the EU economy to experience an extraordinary inflation rate that reached 9.2 % the same year, as mentioned in the latest European Commission article[42]. The same article specifies that housing, water, electricity, gas, and other fuel costs experienced the greatest surge in 2022, with an average increase of 18.0 %. Transportation costs saw an average rise of 12.1 %, while food and non-alcoholic beverage prices increased by an average of 11.9 %. The remaining categories all witnessed varying degrees of price growth in 2022, ranging from 2.0 % to 8.1 %, except for communication prices, which experienced a marginal decline of 0.1 %.

Therefore, the final years of the historical series require special attention due to these significant fluctuations. To ensure that these unconventional fluctuations do not have unexpected effects on the outlook, it is important to implement a specific approach that accounts for these unique circumstances in the data.

3.1 State of knowledge on outlooks

To date, there are two important outlooks in the realm of material flow accounts: *The Global Material Resource Outlook to 2060* (OECD, 2019) and the *Global Resource Outlook (GRO)* (International Resource Panel, 2019) (the 2024 GRO is expected to be published in early 2024). The first study presents global projections of materials use and their environmental consequences, providing a quantitative outlook to 2060 at the global, sectoral and regional levels for 61 different materials. The OECD study explains the economic drivers determining the decoupling of economic growth and materials use, and assesses how the projected shifts in sectoral and regional economic activity influence the use of different materials. The OECD foresight exercise takes a demand-based approach, focusing on the evolution of the economic drivers of material use using macroeconomics modelling tools (OECD, 2019). The second work, edited by the International Resource Panel, builds two different scenario projections for resource efficiency and sustainable production and consumption at the global level up to 2060. The *Towards Sustainability* scenario is built on the hypothesis of more ambitious and broad-based suite of actions by government, business and households to improve resource efficiency, decouple economic growth from environmental degradation, and promote sustainable production and consumption. Instead, the *Historical Trends* scenario provide projections on the assumptions that observed trends and relationships over the decades to 2015 continue into future decades, these driving trends include primarily population growth and per capita economic growth, along with trends in the material intensity of economic activity, rates

42 https://ec.europa.eu/eurostat/web/products-eurostat-news/w/DDN-20230309-2

and patterns of urbanization, technological change within sectors, and climate policy outcomes (International Resource Panel, 2019).

3.2 Methods to develop outlooks

Differently from the outlook exercises reviewed in the previous section, that employ integrated modelling approaches to build scenarios under different assumptions, the outlook exercise here proposed will try to assess the *most likely development for the data underpinning each of the six EEA indicators*. The rationale behind the alternative methodologies is to develop a scientifically sound tool which is easy to update and replicate once new historical data will be released.

3.2.1 Econometric model

Macro-econometric tools use historical data collected over time and analyze them using statistical and econometric methods. This approach allows us to look both at the past and the future to gain a medium-term perspective about the dynamics of a macro-level indicator (2022-2035).

We use an **autoregressive multivariate model (AR)** to forecast the future values of each indicator based on its own past values and other drivers' values. In simpler terms, when we talk about AR (autoregressive) models, we are assuming that the value of a certain indicator at a specific time depends on its past values and also on what we expect other related factors to be. The choice of an autoregressive multivariate model represents a compromise between more refined time-series approaches (e.g. ARIMA) and a tractable model which is easy to update. As for the functional form, due to the limited length of the series, we just consider one autoregressive component and contemporary changes of drivers. A more general model (e.g. adding more than one lag of the dependent or independent variables as covariates) would require longer times series to have a sufficient statistical power.

The general estimation equation is:

$$\Delta log(Y_t) = a + \rho\ log(Y_{t-1}) + \beta_1\ \Delta log(X_t^1) + \cdots + \beta_j\ \Delta log(X_t^j) + \epsilon_t \qquad (1)$$

where $\Delta log(Y_t)$ is the yearly change in the dependent variable (either one of the six indicators) in year t, a is a constant term (representing the average growth rate when all other independent variables are set to zero), $log(Y_{t-1})$ is the autoregressive component, corresponding to the indicator's value in the previous year; $\Delta log(X_t^j)$ is the yearly change of a set of *j* independent variables – extensively explained in the following section; ϵ_t is the disturbance term.[43] Equation 1 is estimated with the ordinary least squares estimator. For ratios (recycling rate, landfilling rate and CMUR) the indicator is not log transformed.

To summarize, the following econometric specifications are used for the six indicators (Table 3.1):

43 When conducting forecasting based on drivers' projections and explicitly considering the time series dimension of the indicators, it is crucial to account for stationarity. Stationarity refers to the statistical properties of a time series remaining constant over time in terms of its mean, variance, and autocovariance. Stationary time series are easier to model and forecast accurately compared to non-stationary series. By applying a logarithmic transformation to our indicators, we stabilize the variance of the series and make it more likely to be stationary.

Table 3.1 Econometric specifications

EEA indicator	Specification
Material footprint	$\Delta log(Y_t) = a + \rho\ log(Y_{t-1}) + \beta_1\ \Delta log(GDP_t) + \beta_2 \log(Pop_t) + \beta_3 \Delta Food_t + \beta_4 \Delta CokeRefineries_t + \beta_5 \Delta Construction_t + \epsilon_t$
EEA consumption footprint	$\Delta log(Y_t) = a + \rho\ log(Y_{t-1}) + \beta_1\ \Delta log(GDP_t) + \beta_2 \log(Pop_t) + \beta_3 \Delta Food_t^{coicop} + \beta_4 \Delta Housing_t^{coicop} + \beta_5 \Delta Transport_t^{coicop} + \epsilon_t$
Waste generation	$\Delta log(Y_t) = a + \rho\ log(Y_{t-1}) + \beta_1\ log(GDP_t/GDP_{t-1}) + \beta_2 \log(Pop_t/Pop_{t-1}) + \epsilon_t$
Landfill diversion (% of total treatment)	$\Delta Y_t = a + \rho\ Y_{t-1} + \beta_1\ \Delta log(GDP_t) + \beta_2 \log(Pop_t) + \epsilon_t$
Waste recycling (% of total treatment)	$\Delta Y_t = a + \rho\ Y_{t-1} + \beta_1\ \Delta log(GDP_t) + \beta_2 \log(Pop_t) + \epsilon_t$
CMUR	$\Delta Y_t = a + \rho\ Y_{t-1} + \beta_1\ \Delta log(GDP_t) + \beta_2 \log(Pop_t) + \epsilon_t$

3.2.2 Selection of relevant drivers and construction of the outlook

In line with the work conducted by IRCrES in 2013 for the ETC-SCP on forecasting of various environmental pressures (EEA, 2013) and by IRCrES-SEEDS in 2017 for the ETC WMGE on forecasting waste generation (ETC-WMGE, 2017), we propose a multivariate econometric forecasting strategy based on drivers' projections.

In multivariate forecasting, other time series variables are involved in producing the forecasts. Population growth and economic activity (measured by growth in gross domestic product - GDP) are commonly seen as the two most important drivers of natural resource use (International Resource Panel, 2019; OECD, 2019), together with demographic, technological, and structural change factors (EEA, 2019).

The IPAT model is a theoretical framework that offers a conceptual basis for defining the key drivers of the AR model. It breaks down the factors influencing environmental impact (I) into three key components. First, "Population" (P) refers to the size of the human population. A larger population typically results in greater resource consumption and environmental pressure. Second, "Affluence" (A) relates to the level of economic prosperity and consumption within a society; higher affluence generally corresponds to increased resource use and waste production. Finally, "Technology" (T) refers to the state of technological advancement and efficiency in resource utilization. Technological innovations can either exacerbate or mitigate environmental impacts. The IPAT model expresses environmental impact (I) as a product of these three elements through the identity I = P x A x T. This model underscores that addressing environmental challenges requires considering population dynamics, economic development, and technological innovation as interconnected factors influencing sustainability and environmental outcomes. Resource efficiency, or I/GDP, which is largely driven by knowledge development and technological development is used as proxy variable for technological innovation. The IPAT identity can be operationalized as:

$$I = Pop \times (GDP/Pop) \times (I/GDP) \qquad (2)$$

This equation can be used for decomposition exercises, where the assumption is that each driver has unitary elasticity. However, equation 2 cannot be estimated via econometric models as it implicitly assumes unitary elasticity of I with respect to each driver. The so-called STIRPAT approach was derived to overcome this limitation, where regressions are run with I as the dependent variable and Pop and GDP/Pop as independent variables, leaving technology (or, better, environmental efficiency) as a ‘residual’ component which is accounted for by assuming non-unitary elasticities of GDP and population (York et al., 2003). More specifically, the STIRPAT approach estimates a regression of the type:

$$\log(I) = a + \beta \log(Pop) + \gamma \log\left(\frac{GDP}{Pop}\right) + \varepsilon \quad (3)$$

or, rearranging:

$$\log(I) = a + (\beta - \gamma) \log(Pop) + \gamma \log(\mathrm{GDP}) + \varepsilon \quad (3)$$

which is equivalent to equation (1). In this context, whenever $\gamma \neq 1$ and $\beta - \gamma \neq 1$ we have a deviation from the assumption of unitary elasticity. More specifically, as long as $\gamma < 1$ and $\beta - \gamma < 1$ we have a situation where the dynamics of the environmental impact is decoupled from both economic and demographic growth. The main reasons for such decoupling(s) are technological improvements and/or structural change (*T* in the IPAT equation). Both these aggregate changes could (or could not) be driven by environmental policy. Within our simple modelling approach, it is not possible to disentangle the contribution of technological change, structural change and policy to the deviation of estimated coefficients β and γ from, respectively, 1 and 2. However, these driving forces (policy, technology, and structural change) are implicitly accounted for in the estimation of the regression coefficients.

The focus on GDP and population is also motivated by the availability of benchmark long run projections and forecasts to be used as an input for our outlook exercise.

As for technological and structural change, instead, no forecast or projection is available. Technological change is an inherently uncertain process. While some hint about the contribution of technological change to macroeconomic dynamics is possible, evaluating future trends of technological change in specific technological domains (e.g., circular economy) and their impacts on environmental outcomes is not possible. In the IPAT framework, an indirect measure of the role played by technological change is the coefficient estimated for GDP: a coefficient below 1 indicates a relative decoupling (absolute if <0) and points to an improved technology. In calculating the outlook, the assumption is that decoupling continues with the same rate as in the period used for estimation.

For what concerns drivers related to structural change, instead, we consider it to be relevant mostly for measures considering all sectors of the economy (i.e., material footprint and EEA consumption footprint). Changes in the sectoral composition of the economy contributes to changes in environmental outcomes as substantial differences exist in the material use per unit of monetary output across all sectors. For example, while many services require very limited amount of materials per unit of monetary output, other sectors (e.g. construction) have very large material intensity. Structural change is accounted for by means of additional independent variables (just for material footprint and EEA consumption footprint). To identify the relevant sectors, we consider their relative importance for the material footprint (Table 3.2) and consumption footprint (Table 3.3).

Three macro-sectors account for almost 60 % of the EU-27 material footprint in 2020, while just contributing to 9.5 % of employment and 20.4 % of gross value added (Table 3.2). Instead, the top three 1-digit categories of consumption purposes (COICOP, Table 3.3) account for almost 2/3 of the consumption footprint in 2021. As for sectors of Table 3.2, the considered driver is the ratio between apparent consumption of products of the sectors (domestic gross output, plus import less export) of the sector divided by the total apparent consumption of products. For consumption categories in Table 3.3, instead, the ratio between consumption of the specific group and total consumption is considered.

Table 3.2 Sectors considered to account for structural change for material footprint: share of EU27 totals in year 2020

CPA codes	Description	Gross value added	Employment	Material footprint
A01 + C10-C12	Food	3.7%	2.8%	17.7%
C19	Coke and refineries	0.07%	0.12%	3.5%
F + L	Construction	16.7%	6.6%	37.2%
	Total	20.4%	9.5%	58.4%

Source: Eurostat

Material footprint: *https://ec.europa.eu/eurostat/databrowser/view/env_ac_rmefd*

Employment and gross value added: *https://ec.europa.eu/eurostat/databrowser/view/nama_10_a64*

Table 3.3 Consumption categories considered to account for structural change for the EEA consumption footprint: share of EU27 totals in year 2021

COICOP 1-digit	Description	Expenditure	Consumption footprint
01	Food and non-alcoholic beverages	14.3%	21.8%
04	Housing	25.0%	30.7%
07	Transport	12.1%	13.1%
	Total	51.4%	65.6%

As for additional drivers for which no official projection is available, we envisage two options:

- we assume that these drivers remain constant at their latest historical value (default option);
- we estimate a linear projection of drivers for future years.

The default option (see above) is used to limit the risk of obtaining projected trends that are not credible and could emerge for some countries. For example, it could be that a recent past trend of growing food consumption share is then projected to result in food consumption shares that exceed 100 %.

The estimation of the outlook of the six indicators will generally follow a two-step procedure:

- As a first step, the relationships between our indicators and their drivers are estimated by means of historical data;
- As a second step, estimates of the parameters of the previous equation are used in combination with projected values of population and GDP to estimate future trends of the selected indicators.

Estimations will consider both actual data and more up-to-date data developed by the ETC CE in the nowcasting work (chapter 2). The estimation of equation 1 will only consider available historical data in order to limit measurement errors. However, in building the outlook, we will consider nowcasted data as an input for the forecast in the years for which the nowcasting is available.

The multivariate econometric forecast strategy proposed for the six indicators can be easily implemented and updated in Excel. The outlook will be performed both for single countries and for the EU-27 as a whole. EU-level analysis allows to work with a rather stable series for drivers and indicators. While this ensures lower volatility, the absence of major changes could limit the predictive power of the regression. Moreover, the aggregate trend does not allow to account for heterogeneous relationships across different countries between drivers and indicators.

The consideration of country-level specificities turns out to be particularly relevant where the relationship between drivers and indicators is characterized by country specificities (e.g. decoupling patterns, country-specific policies).

As the exploration of both EU-wide and country-level outlooks could be based on the same methodological framework, the tool considers both approaches.

To deal with uncertainty of the prediction, for the EU-27 we also report **confidence intervals**. They are estimated by adding/subtracting to the predicted growth rate the root mean square error of the regression multiplied by the Student's t critical value. These estimated values are reported, respectively, as *upper bound (u.b.) and lower bound (l.b.)* in the figures. Due to the very small sample size used for the regression, we consider a 2/3 (p-value<0.667) probability as the critical value.[44] In short, the confidence interval indicates that the probability of having an actual realization outside the confidence interval is lower than 33 %.

3.2.3 Data sources

Data on **GDP**[45] (for 2004-2020, chain linked volume at 2015 prices) and **population** (2004-2020) are retrieved from Eurostat. Specifically, GDP is in chain-linked volume, a form of GDP computation that allows to remove the effects of monetary variables – such as inflation – because it calculates the total value of GDP for each year using the prices of the previous year. Then, these adjusted figures are connected, creating a time series that focuses on changes in production volume over time.

Projections for population (up to 2060) are also available from Eurostat (main scenario).[46] For what concerns projections for GDP, we consider alternative official forecasts for GDP. The European Commission provides **GDP forecasts** (with 5 years interval) for member states to be used in climate and energy models up to 2050 in the 'EU Reference Scenario 2020 - Energy, transport and GHG emissions - Trends to 2050'.[47]

The consideration of **additional drivers** (e.g. structural change, technological change, etc.) for which no official forecast is available will be based on data available from Eurostat (structure of the economy from the *nama_10_a64* database).

3.2.4 The role of policy

The focus on a data-driven approach considering the main socio-economic drivers of environmental pressures calls for a discussion on the implicit or explicit assumptions made about the role played by environmental and other policies as well as other drivers that were not explicitly accounted for in the proposed methodology (e.g., technological and structural change).

The proposed approach does not explicitly measure the contribution of policy to the evolution of CE-related indicators. This choice is motivated by two classes of considerations. First, the portfolio of overlapping policies with direct or indirect implications for each of the six indicators is very wide and heterogeneous. These include binding targets, technology standards, fiscal-based incentives, voluntary schemes, etc. Evaluating the specific contribution of each policy is not possible as all other instruments should be taken into account to remove confounding factors. Secondly, even if it was possible to construct indicators of policy stringency, the extrapolation of future changes would be characterized by a very high degree of uncertainty and arbitrariness.

The analysis of specific policy impacts would require the existence or construction of policy indicators that are possibly included as drivers of impact indicator in a multivariate model. Policy indicators can be

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44 This threshold is also considered in the IPCC 6th Assessment Report.

45 GDP and main components (chain linked volumes - 2015)

46 https://ec.europa.eu/eurostat/web/population-demography/population-projections/database

47 https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en

obtained by real world data (e.g., pricing correlated to taxes, like energy taxes, EU ETS prices), by categorical policy indicators which capture the intensity of a policy action (continuous or discrete indicators) and eventually threshold indicators (policy being present or not) to assess the presence of 'breaks or relevant events which change the pattern (e.g., policy events, recessions, energy shocks due to wars, pandemic crises, etc..).

As far as policies are concerned, it is worth noting that their inclusion as a driver of economic and environmental performances is often challenging, given the heterogenous nature of policies in the real world. Policies are implemented at various levels (European, national, regional), are introduced at different periods of time, are diverse (monetary taxes and fees which are usually managed by countries and regions, emission trading systems, which in the EU presents a single price for all agents, voluntary schemes, command and control). For those reasons, policy indexes are often used, constructed as 'continuous indexes' or categorical / dummy indexes. One example is the OECD Environmental policy index of stringency, which summarizes different features of national policies and creates a dynamic / heterogenous index (Botta and Kozluk, 2014). In the OECD Environmental policy index different policies are weighted according to some transparent (but mostly arbitrary) weighting scheme.

In this work on outlooks, given that (i) pricing related variables are available for energy realms (e.g. energy taxes) but are not here directly relevant as drivers, (ii) policy indexes are not available from official sources or are too general (e.g. the OECD EPS index), and (iii) the analysis of events/breaks is undermined by the limited length of the time series[48], we opt – in coherence with the AR model – for capturing policy effects through the change which occurs over time in the coefficient that captures the relationship between the impact and GDP. In a nutshell, policy related and technology related effects on impacts (on decoupling) are absorbed by that coefficient. Namely, by the reduction of the 'elasticity' of the impact with respect to GDP.[49]

Being the background conceptual model IPAT, all effects of the T term are captured by the coefficients of I and A. If a reduction of the estimated coefficient of GDP is observed, the interpretation can be developed by using complementary information on the technological change and regulatory changes that a given country or the EU has observed in the past years.

In addition, the lags of specific drivers in the model also represent dynamic inertia. The past is thus capturing the evolution of the model (sort of structural change factor).

48 It is also worth noting that the policy effect is less clear cut in those realms compared to energy and climate. First, we are often in presence of a set of regulations which touch different waste streams (e.g., packaging, WEEE, construction and demolition, etc..) instead of having policy pillars like the EU ETS in climate policy. Second, in most (federal) countries, waste regulations are implemented at regional and municipal levels (Ferraresi et al., 2023). As example, Italy presents more than 20 different landfill taxes across regions. It is then almost impossible to summaries in a single index the country commitment without moving within the intra country variations. In addition, some 'policy event' are in reality only strategies, such as the EU Circular economy strategy in 2015, with update in 2020, implemented through a diversified portfolio of different regulations (marked based, technology based, command and control).

49 To provide further elaboration, if the estimated coefficient associated with the variable of GDP growth is negative and significant, it would indicate an absolute decoupling, meaning that as the GDP grows, there would be a decrease in waste generation. On the other hand, if the estimated coefficient of the variable has a positive sign and a low coefficient (< 1), it would suggest relative decoupling, where the rate of waste generation is growing, but at a slower pace compared to GDP growth. The interpretation of decoupling in case of declining GDP (e.g. for year 2020 due to the Covid-19 outbreak) could be problematic. In presence of absolute decoupling, a decline of GDP would result in an expected increase in environmental pressures, which could be surprising for many of the relevant indicators.

In summary, it should be stressed that the outlook does not represent the most likely evolution of the indicators in absence of any policy. Instead, it represents how the indicators are expected to evolve given the current set of policies and the expectations about future policies. For example, the effects of the circular economy strategies approved and implemented by the EU is likely to fully materialize just in a long-term horizon.

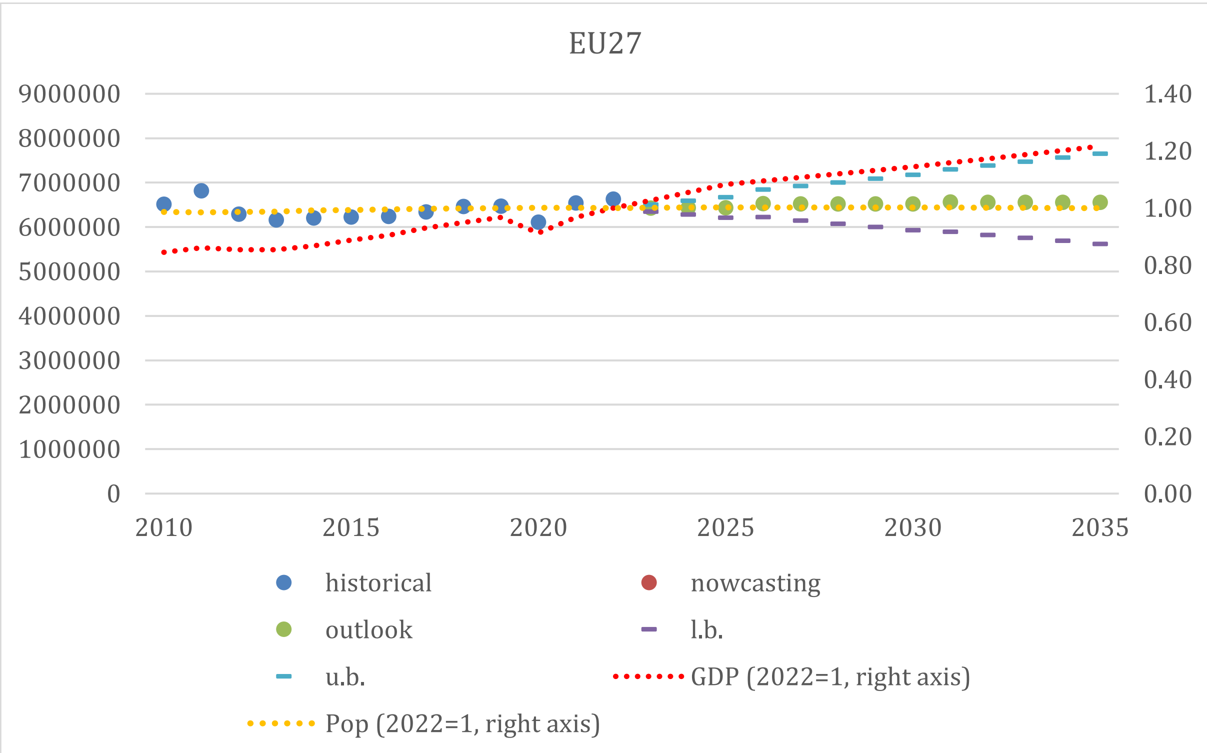
3.3 Results

This section reports the main results of the outlook exercise. For each indicator, we show the outlook for the EU-27 as a whole and briefly comment on the aggregate outlook and country-specific results. Country-specific results (estimated coefficients and outlook) are instead reported in the **Annex**. We note that the outlooks are based on historical trends and changes in the predictors (i.e., population and GDP growth) and do not account for the impact of newly introduced policies that could lead to additional changes in the future trajectories of the indicators (e.g., policies targeting dematerialization, fossil-fuel phase out, ramping up recycling rates, consumption-side changes, etc.).

3.3.1 Material footprint

Results of the outlook exercise for the material footprint are provided in Figure 3.1. Note that the data point for 2022 is based on the nowcasted data from Eurostat (see section 2.2.4 for details), but as it was taken directly from Eurostat we did not mark this data point as "nowcasted data" in the figure (the same applies to results figures at member state level for the material footprint given in the annex).

Figure 3.1 Material footprint: outlook for EU-27 (unit in thousand metric tons)



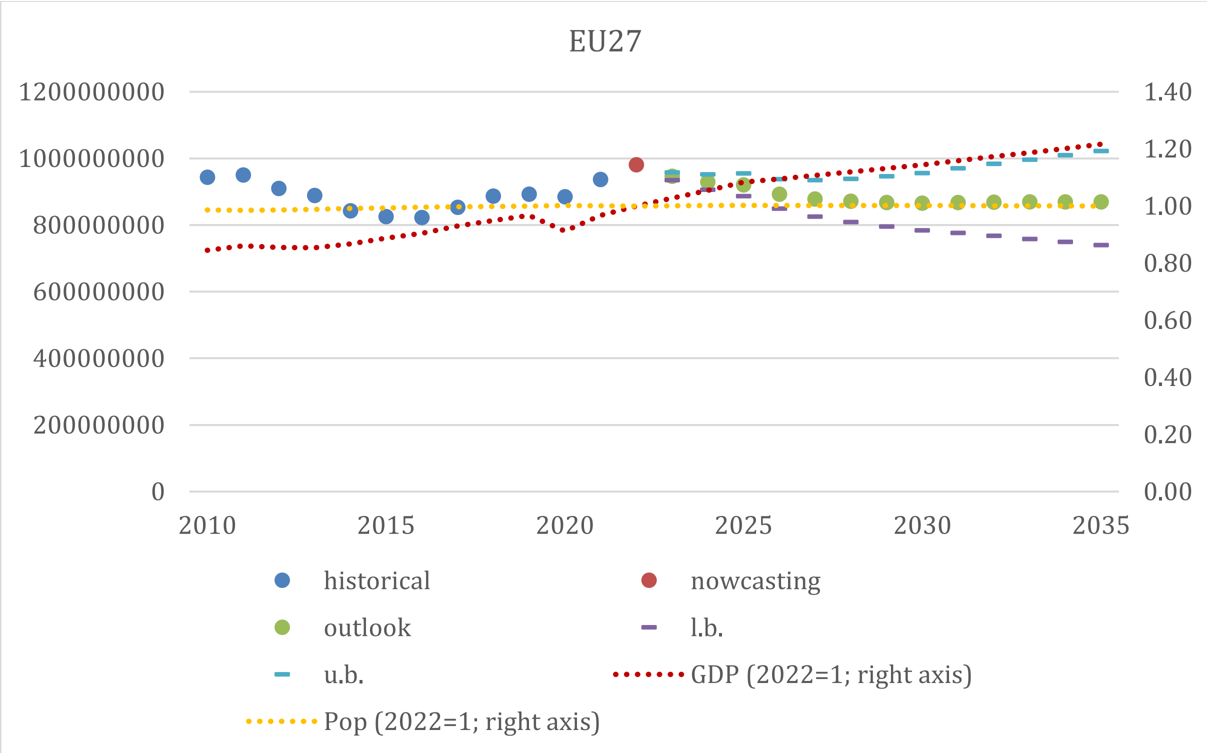
Source: ETC CE calculations based on Eurostat data.

The EU-27 outlook for the material footprint is rather stable until 2035 with no relevant deviation from historical values, despite the fact that GDP forecasts show substantial growth (almost +20 % to 2035 with respect to 2022). However, the 66 % confidence interval does not rule out either a moderate decrease or a moderate increase of the indicator. This stable trend until 2035 at the aggregated EU-27-level is also found in the outlooks for most EU member countries. Overall, at the EU-27 level, while GDP is forecasted to increase – leading to a potentially higher material footprint – population is predicted to be stable around its historical average value.

3.3.2 EEA consumption footprint

Results of the outlook exercise for the EEA consumption footprint are provided in Figure 3.2.

Figure 3.2 Consumption footprint: outlook for EU27 (unit in Points)



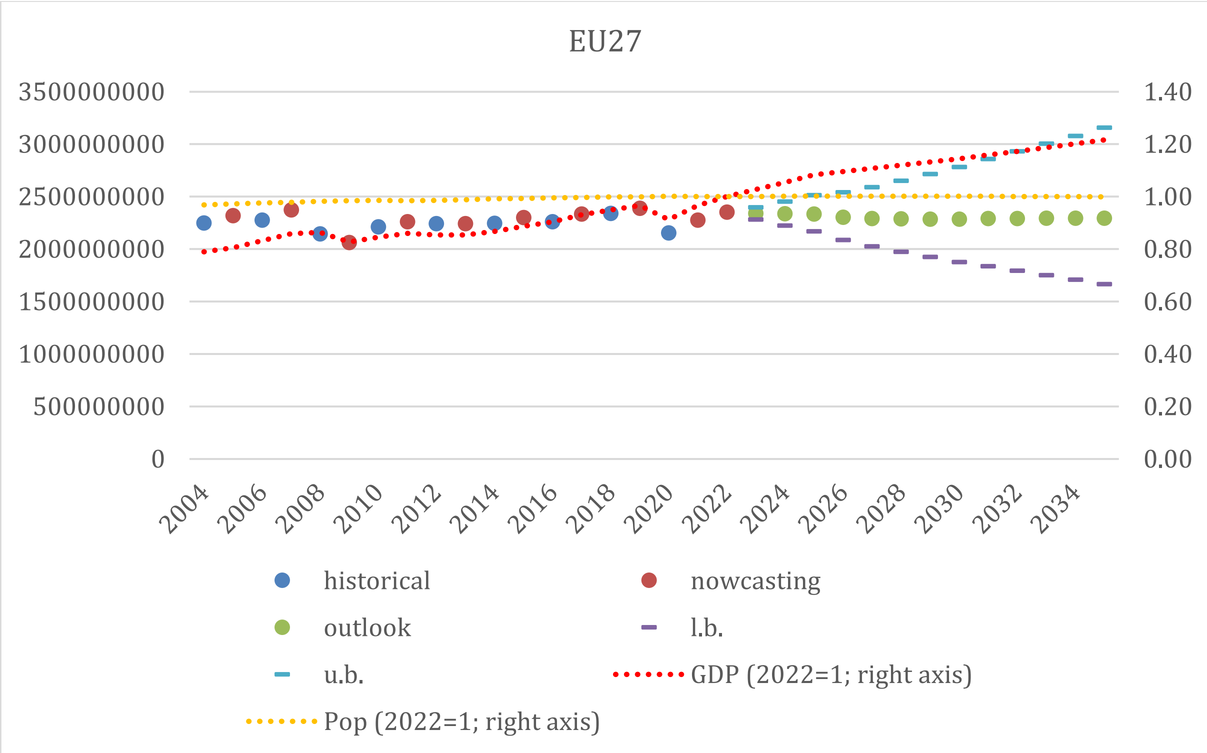
Source: ETC CE calculations based on Exiobase data.

The EU-27 outlook for the EEA consumption footprint indicates a slow decline in the coming years, returning to historical values around 2017. Similar to the previous indicator, the confidence interval does not rule out either a moderate increase or a moderate decrease of the indicator up to 2035. For the EU-27, the gap between population growth and GDP growth could drive this overall trend of decreasing consumption footprint or, at least, slow growth, depending on the consumer's preferences.

3.3.3 *Waste generation*

Results of the outlook exercise for waste generation are provided in Figure 3.3.

Figure 3.3 Waste generation: outlook for EU27 (unit in tonnes)



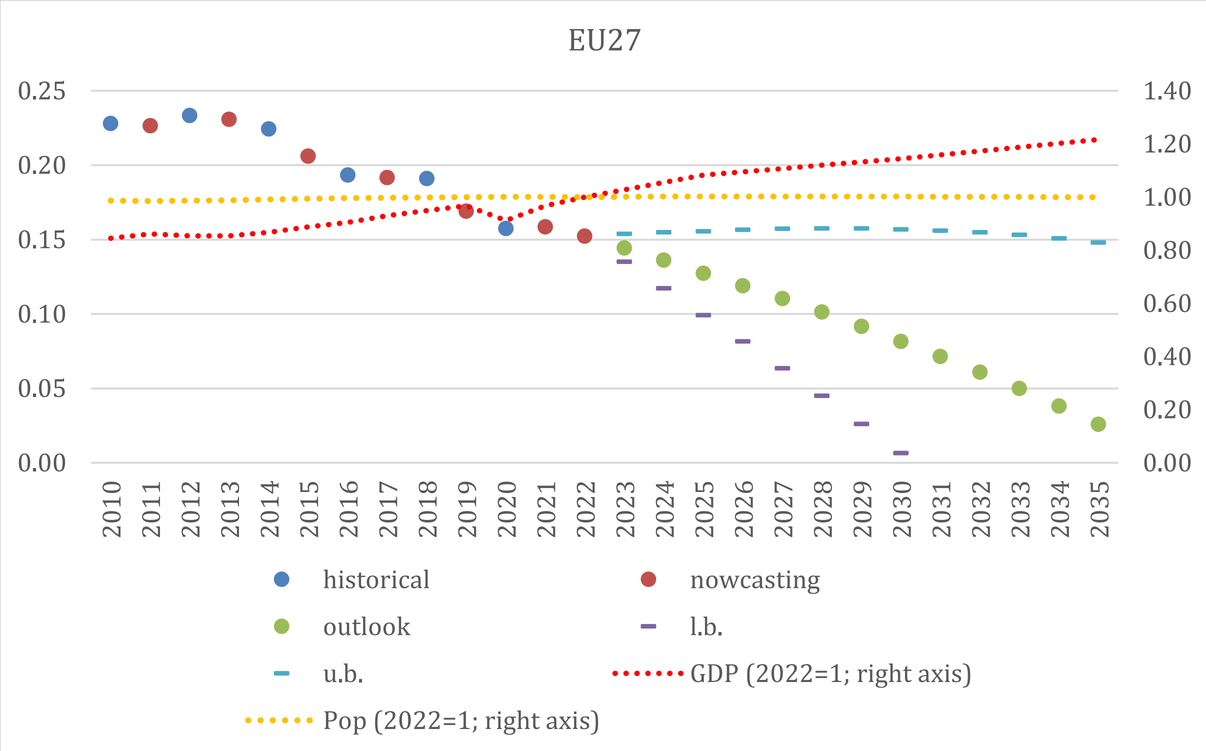
Source: ETC CE calculations based on Eurostat data.

For the EU-27 outlook, the waste generation indicator remains relatively stable until 2035, with no significant deviations from historical values. It should be noted, however, that the degree of uncertainty (size of the confidence intervals) is particularly large for this indicator. Future trends also depend on the attitude and behavior of the population towards waste generation, which is not explicitly modeled in our outlook analysis.

3.3.4 Diversion of waste from landfills

Results of the outlook exercise for diversion of waste from landfills are provided in Figure 3.4.

Figure 3.4 Share of waste disposed in landfills: outlook for EU27



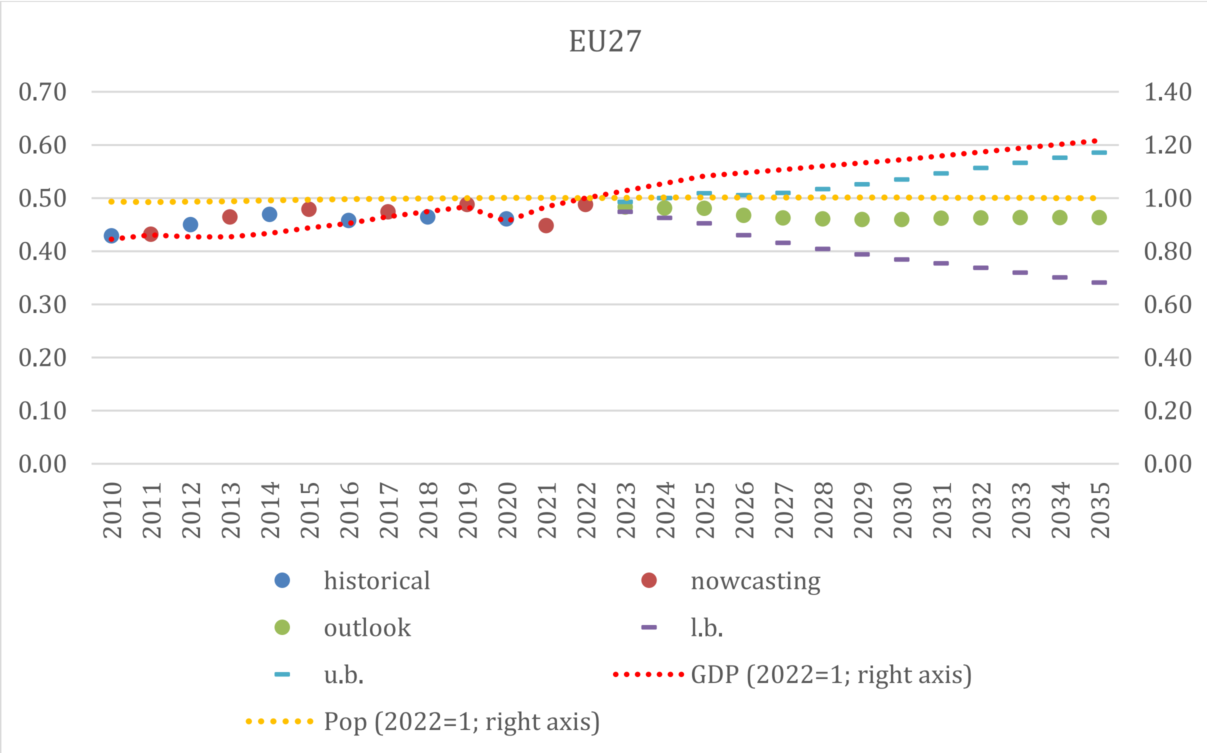
Source: ETC CE calculations based on Eurostat data.

The EU-27 outlook for the share of waste disposed in landfills indicates a progressive and slow decline in the coming years. The value, which was 23 % in 2010, is projected to stabilize at around 3 % by 2035. Note that our outlook doesn't take into account physical limitations, like landfilling or incineration capacity: one can argue that this low shares of landfilling can only be possible if residual waste is diverted to incineration instead. Despite a substantial degree of uncertainty in the prediction, it is possible to rule out with high confidence an increase of the indicator by 2035. At the EU-27 level, while GDP is forecasted to increase, population is predicted to be stable around its historical average value.

3.3.5 *Waste recycling*

Results of the outlook exercise for waste recycling are provided in Figure 3.5.

Figure 3.5 Share of waste recycled: outlook for EU27



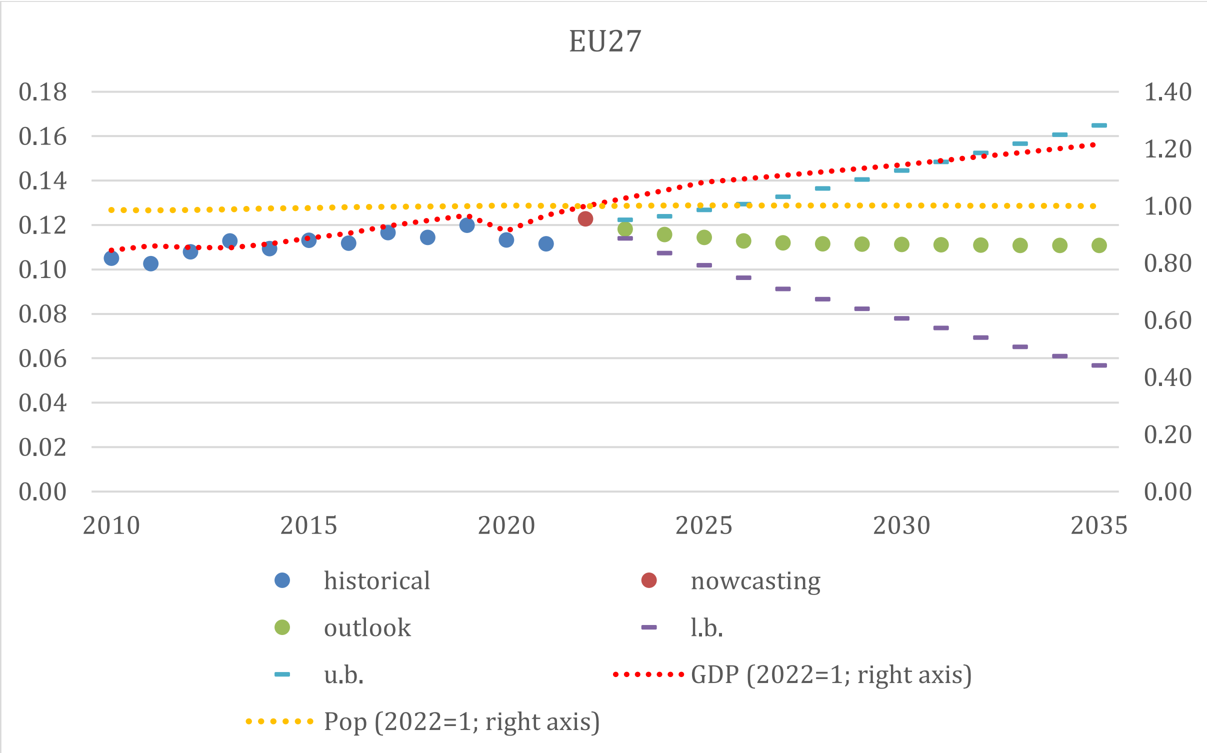
Source: ETC CE calculations based on Eurostat data.

The EU-27 outlook for the share of waste recycled indicates substantial stability in the coming years, remaining within the range of historical values (between 40 % and 50 %). For waste recycling, however, it is not possible to rule out either a moderate increase or decrease of the indicator by 2035. At the EU27 level, it is anticipated that GDP will experience growth, whereas the population is expected to remain stable, hovering around its historical average value.

3.3.6 Circular material use rate (CMUR)

Results of the outlook exercise for the circular materials use rate are provided in Figure 3.6.

Figure 3.6 CMUR: outlook for EU27



Source: ETC CE calculations based on Eurostat data.

The EU27 outlook for the circular material use rate (CMUR) indicates a continuous and slow decline in the coming years, converging to about 11 % by 2035. However, please note that the degree of uncertainty of the outlook is large for the CMUR indicator. We also note that the outlook in this report does not consider any changes that could be triggered by circular economy policies such as, e.g., increasing waste recycling or material efficiency gains that may be able to significantly alter circularity in the EU-27 (for example, see the EEA briefing[50] in which simple "what-if" scenarios where applied to the CMUR to investigate how realistic the doubling target by 2030 would be).

3.4 Discussion and uncertainties

The proposed methodology leaves many degrees of freedom in its implementation. The choice over the various options is detailed and discussed in the previous paragraphs. The first degree of freedom concerns the selection of the independent variables (drivers) used for each indicator and/or for each country. While using the same specification for all countries makes the comparison easier, this comes at the cost of possible misspecification of relationships for some countries. The second degree of freedom has to do with the assumption about the adjustment mechanisms. In the proposed approach we just consider a one-year lag in the dependent variable, but more than one lags could be needed. However, as the series of historical data are very short, there is not enough statistical power to check for these alternative specifications. The third degree of freedom relates to the treatment of structural breaks. For most indicators the time series is currently too short to allow for a proper account of structural break within an econometric framework.

50 https://www.eea.europa.eu/publications/how-far-is-europe-from

Moreover, a special consideration for the last years of the historical series is needed. Indeed, aggregate trends of GDP, population, and environmental performances for the years 2020-2023 are heavily impacted by large oscillations in economic variables due to the Covid pandemics (both restriction measures and fiscal policy interventions) and the Russia-Ukraine conflict. These events could be a source of additional uncertainty for the outlook/nowcasting of the years 2020-2023 which, however, should vanish for the subsequent years.

EEA updatability is ensured by the use of standard Microsoft Excel functions to perform the outlook analysis. While this choice comes at the cost of reducing the flexibility of options (e.g., running various regressions and automatically choosing the best specification for each case), the advantage is that the tool turns out to be extremely transparent and simple.

4 Conclusions

The report provides an overview of possible nowcasting and outlook approaches for each of the six EEA indicators. The review of possible options highlighted that for each of the indicators a nowcasting method exists. The recommended approach for the material footprint was incorporated directly by Eurostat into their datasets after discussion with the EEA and ETC. For the waste indicators (generation and recycling) and consumption footprint, detailed excel tools are provided to the EEA to carry out nowcasts in the future. For the CMUR, it was recommended to rely on Eurostat early estimates which become available with only a T+11 months time delay. However, given the heterogeneous nature of the indicators and underlying data sets, different nowcasting approaches have to be used. The most recent year for which nowcasts can be carried out depends on data availability and the method chosen (e.g., for the material footprint on the ESTAT EW-MFA early estimates).

Furthermore, outlooks can be carried out for all six indicators using an autoregressive analysis and an excel tool was developed by SEEDS to support the EEA in carrying out outlooks in-house in the future. The proposed outlooks approach consists of a streamlined but robust and transparent tool for estimating the most likely development evolution of the six EEA indicators using future projections related to population and economic growth. Additional drivers related to structural change, technological change, and environmental policy were investigated. As it was not possible to obtain official forecasts for these variables, the outlook exercise specified ad hoc scenarios for these variables and evaluated how results change according to the specific assumptions. We recommend that the outlooks based on autoregressive models discussed in this report are complemented with simple “what if scenarios” in the future to highlight the possible impact of specific policies (e.g., material efficiency gains, changes in recycling, alternative consumption patterns, etc.) on the indicator development.

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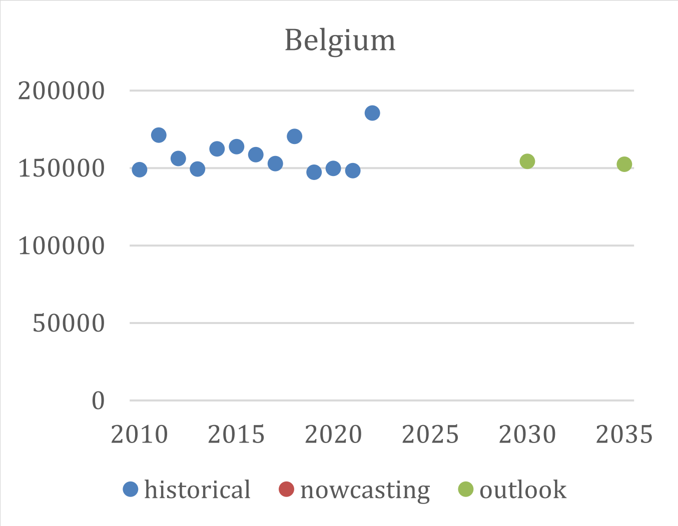
Annex 1 – Country-by-country outlook

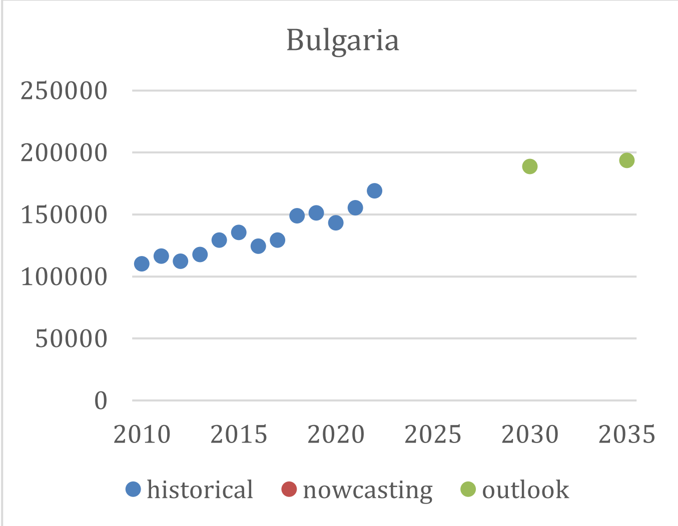
Material footprint

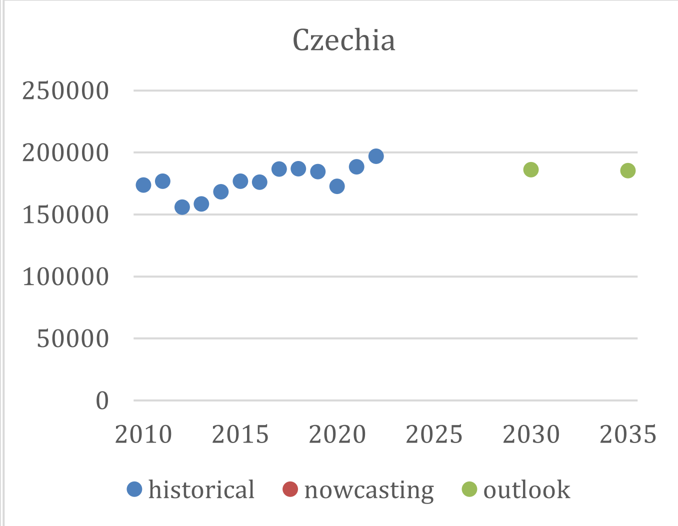
Table A1.1 Results of the econometric exercise

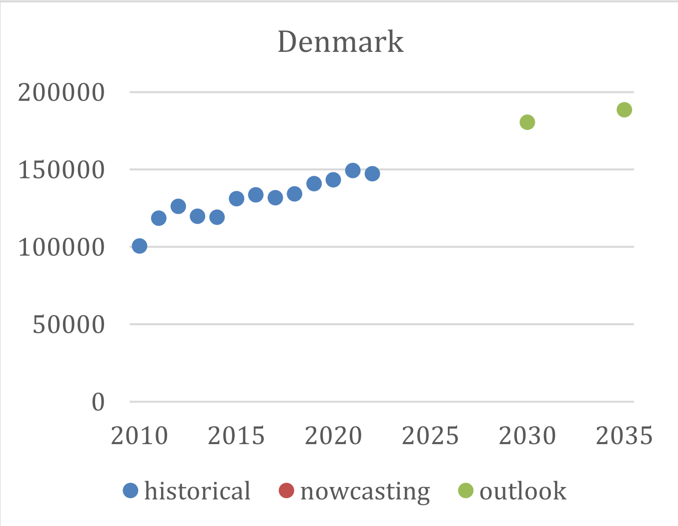
Country	△(F + L)	△(C19)	△(C10-12+A01)	△ln(GDP)	△ln(POP)	ln(MF,t-1)	constant
EU27	0.814	5.616	-7.492	-0.010	-17.633	-1.050	16.477
Belgium	16.364	-3.529	0.119	2.924	7.216	-1.762	20.991
Bulgaria	1.241	3.745	-8.688	1.296	-3.016	-0.035	0.394
Czechia	4.775	2.850	2.358	1.661	-3.494	-0.386	4.644
Denmark	10.713	14.319	9.954	2.447	-27.435	-0.268	3.274
Germany	5.126	10.343	1.118	1.341	-0.076	-1.025	14.418
Estonia*	3.544	-	20.799	1.462	14.129	-0.483	5.031
Ireland	1.090	-123.662	-2.853	-0.270	16.206	-0.970	10.483
Greece	-2.372	3.051	3.653	0.354	-6.150	-0.226	2.619
Spain	-5.310	1.638	6.301	0.929	22.973	-0.944	12.269
France	8.060	10.380	0.733	0.718	3.576	-0.899	12.305
Croatia*	1.956	-	9.430	0.685	-1.091	-0.793	8.634
Italy	15.982	10.737	8.996	1.926	5.615	-0.312	4.204
Cyprus	-1.530	-7.650	-26.274	2.120	-0.157	-0.136	1.242
Latvia	0.343	25.335	9.841	0.180	-2.109	-0.394	4.099
Luthuania	2.710	-8.407	2.815	0.432	0.337	-0.069	0.771
Luxembourg	-22.777	-6228.087	-119.712	2.207	-2.139	-0.446	4.303
Hungary	-3.199	9.050	-24.972	0.421	38.619	-0.339	4.101
Malta	-25.428	0.308	51.914	-0.306	8.668	-0.978	8.259
Netherlands	-2.375	-11.994	-31.037	-1.234	-17.212	-0.320	3.868
Austria	-15.985	-4.665	-11.048	-0.399	4.997	0.112	-1.388
Poland	8.674	12.589	5.750	0.632	-7.898	-0.560	7.503
Portugal	-1.800	3.313	-18.682	-0.130	6.215	-0.566	6.822
Romania	13.817	15.348	9.565	0.634	-4.956	-0.439	5.759
Slovenia	0.459	4.897	2.088	0.587	14.793	-0.645	6.682
Slovakia	0.512	4.639	22.174	1.099	13.196	-0.846	9.458
Finland	-3.616	8.952	-14.063	-3.839	-7.271	-1.085	13.557
Sweden	-20.256	-10.711	27.352	-0.629	7.846	-0.257	3.193

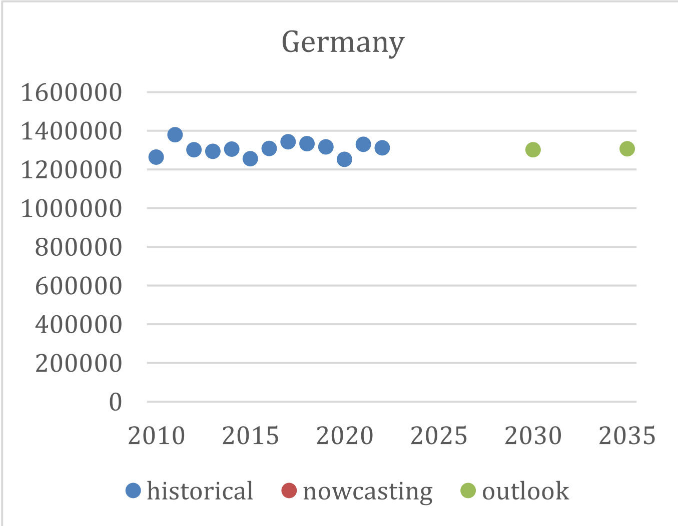
Country	∆(F + L)	∆(C19)	∆(C10-12+A01)	∆ln(GDP)	∆ln(POP)	ln(MF,t-1)	constant
* The inclusion of the C19 variable led to anomalous results. The variable has been excluded							

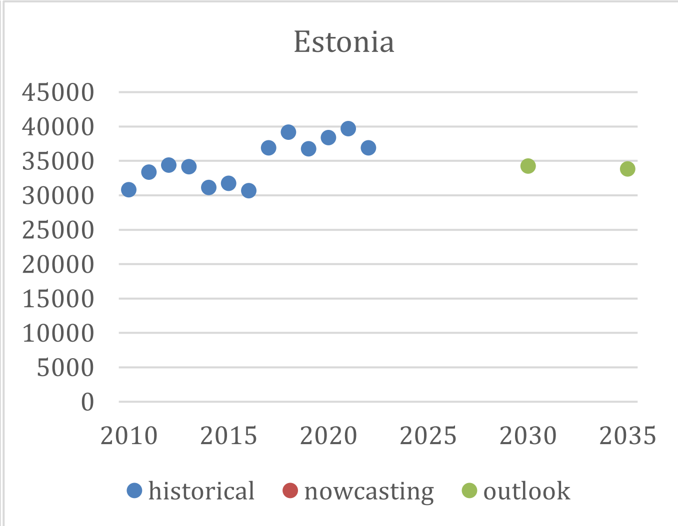


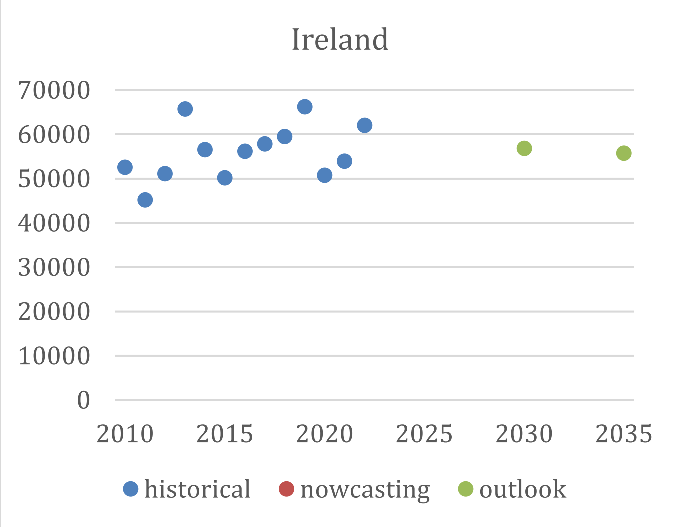








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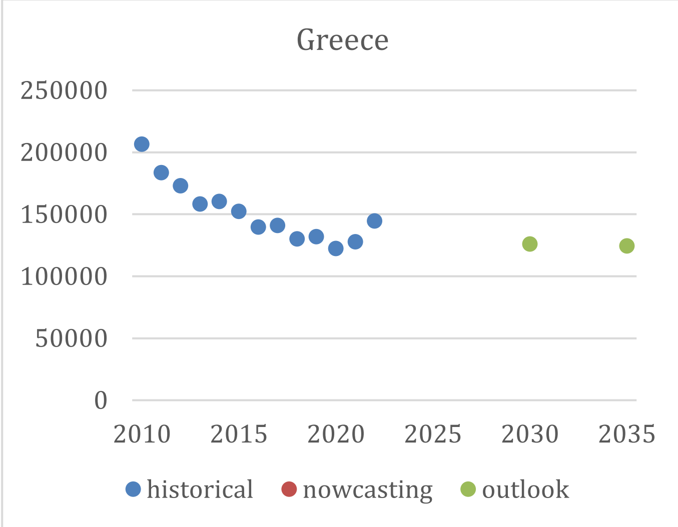
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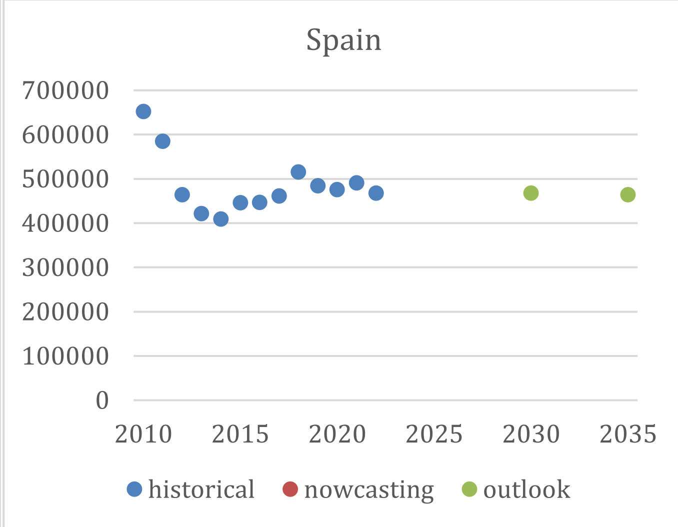
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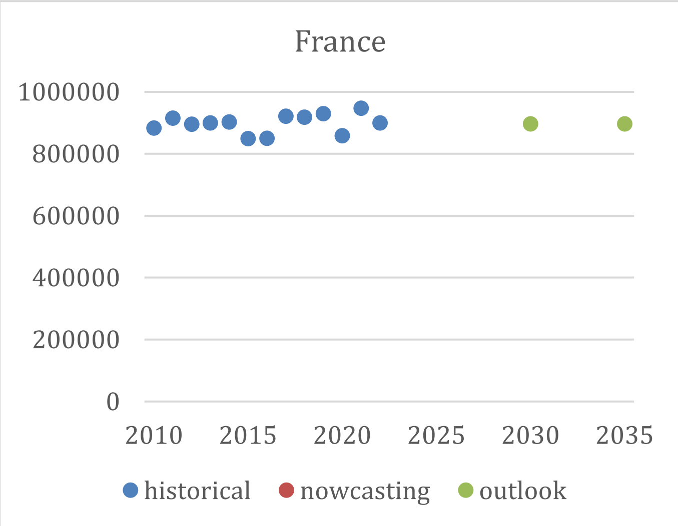
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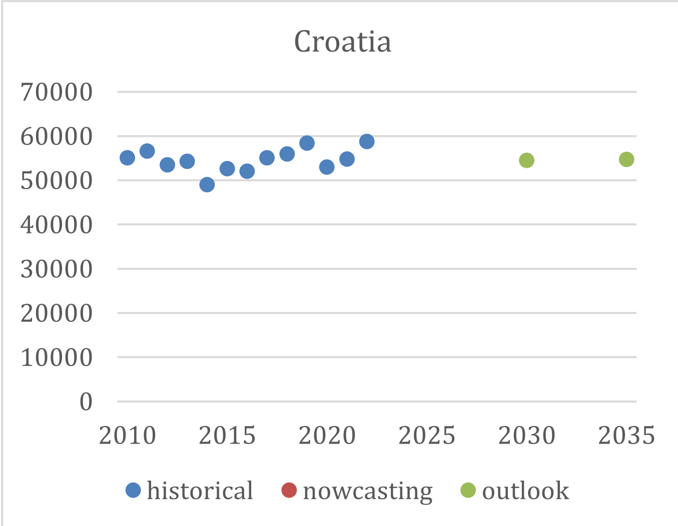
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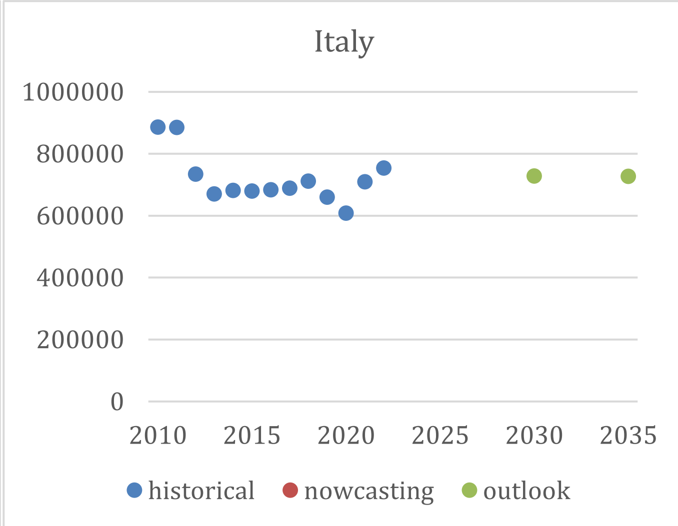
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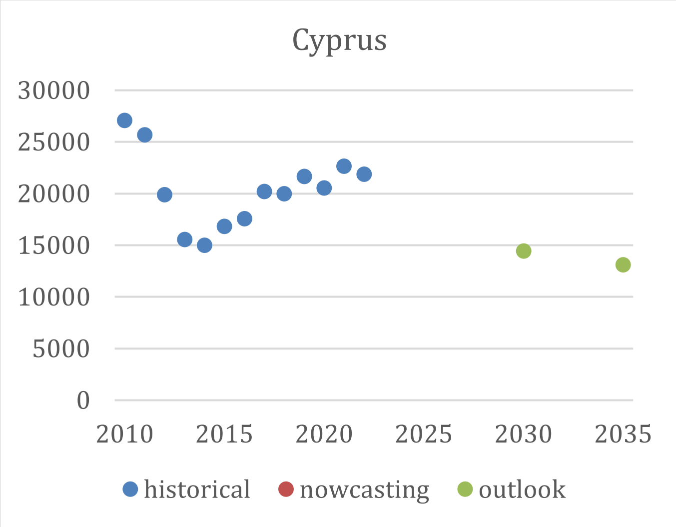
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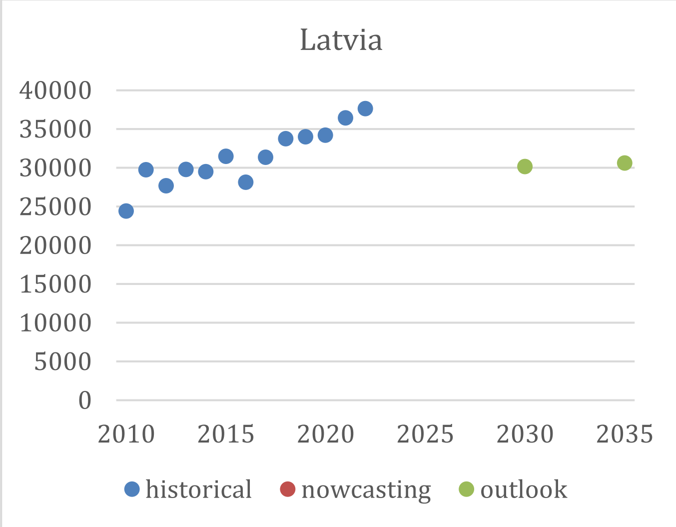
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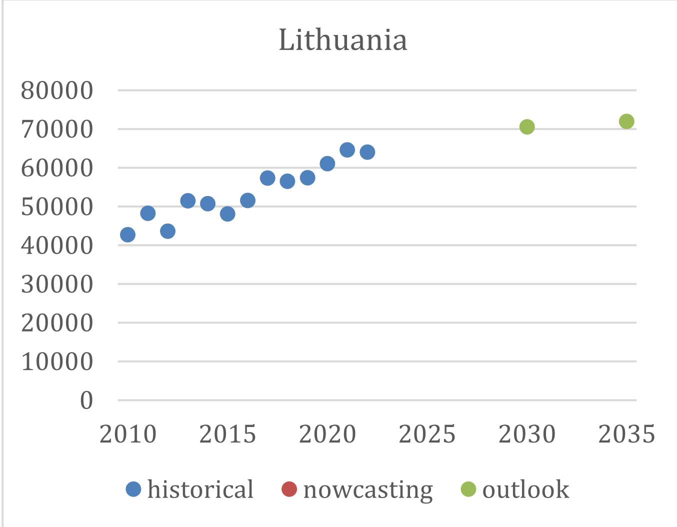
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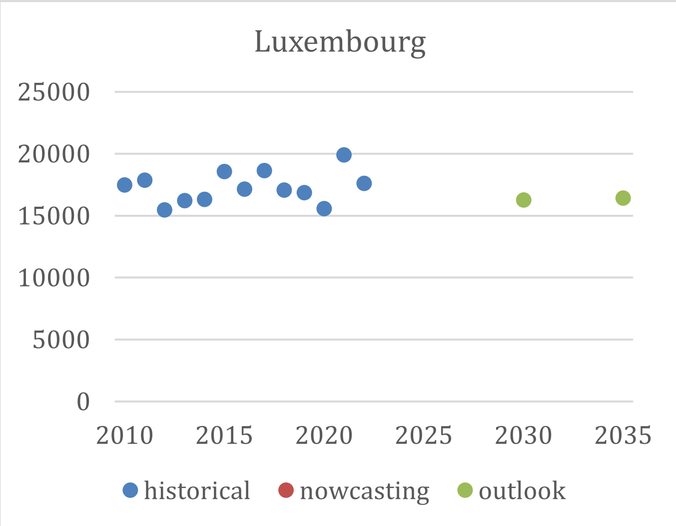
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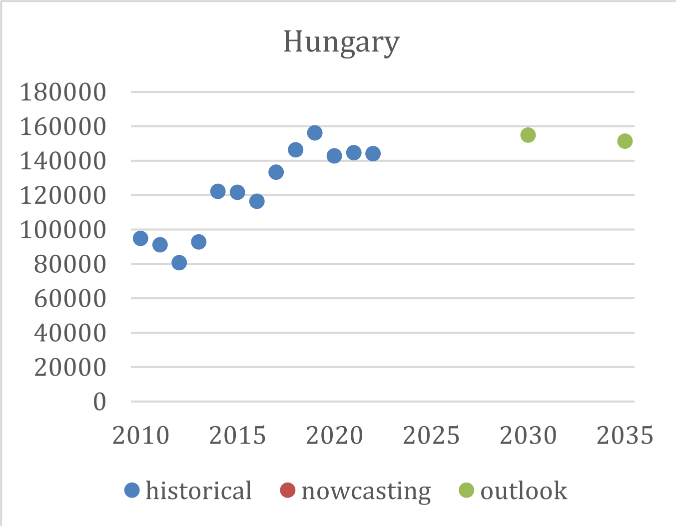
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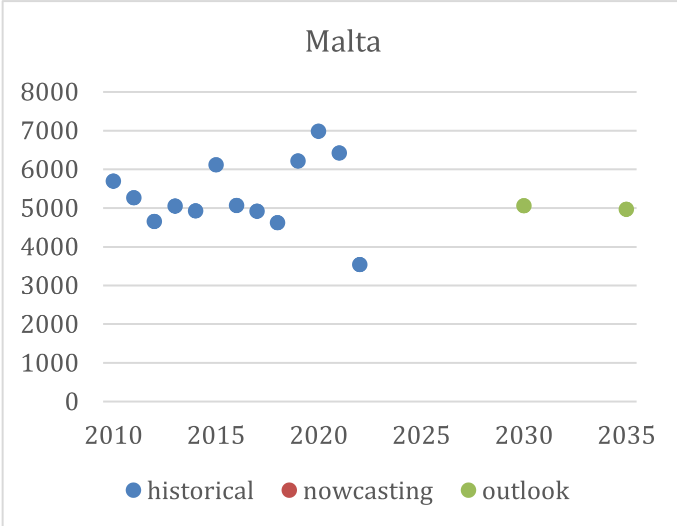
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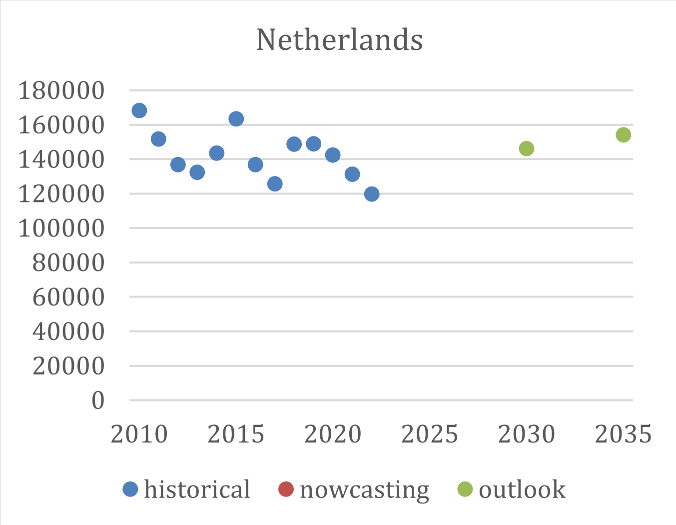
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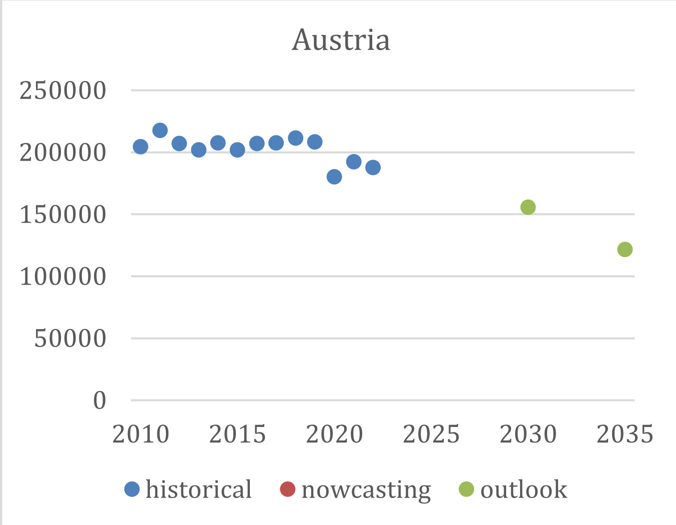
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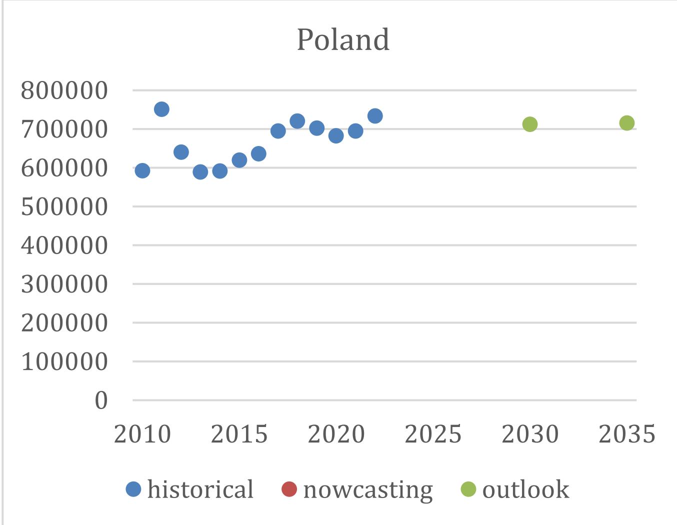
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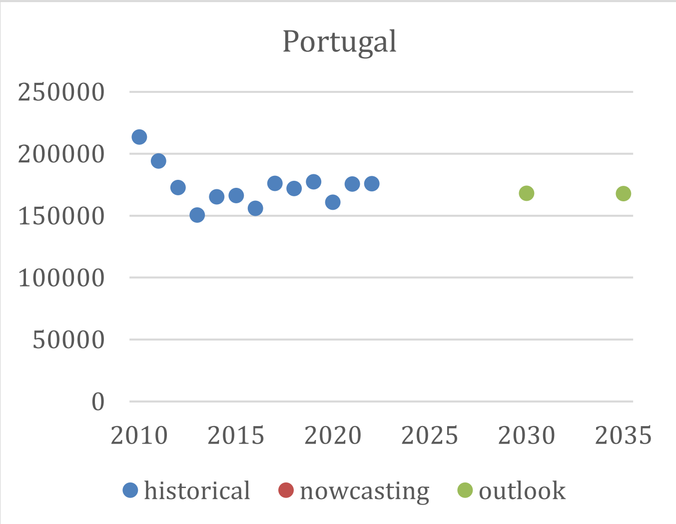
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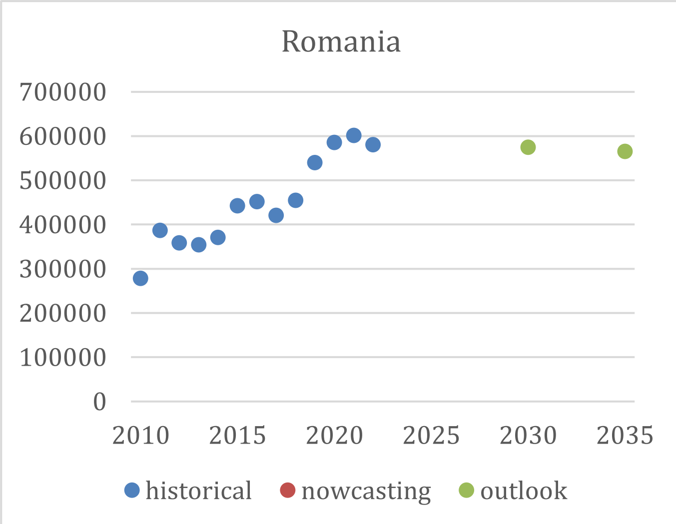
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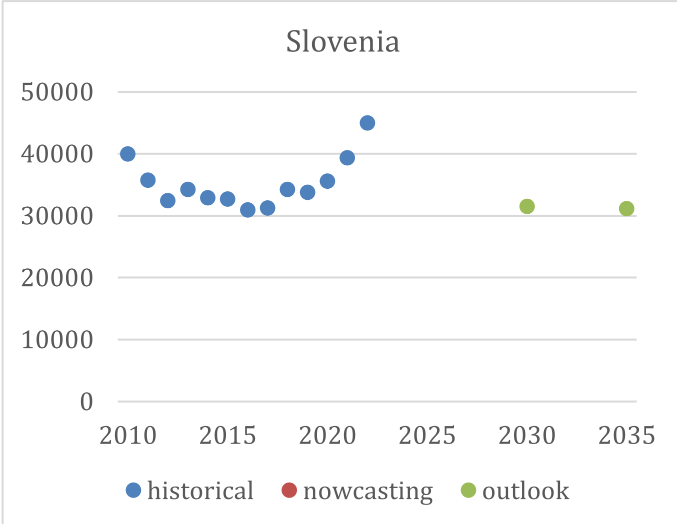
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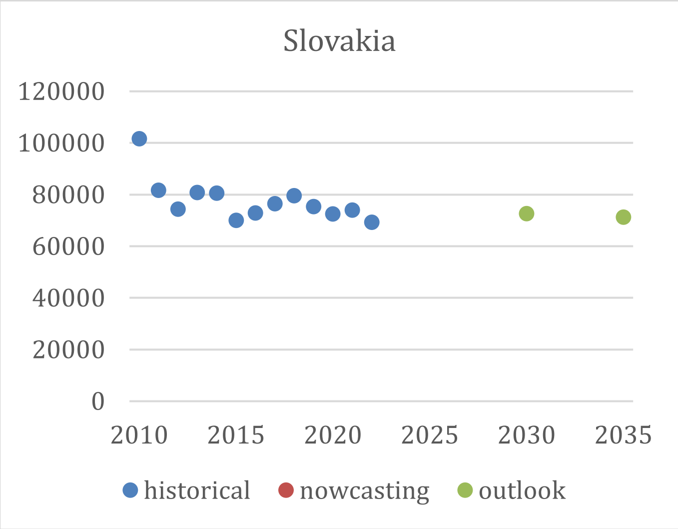
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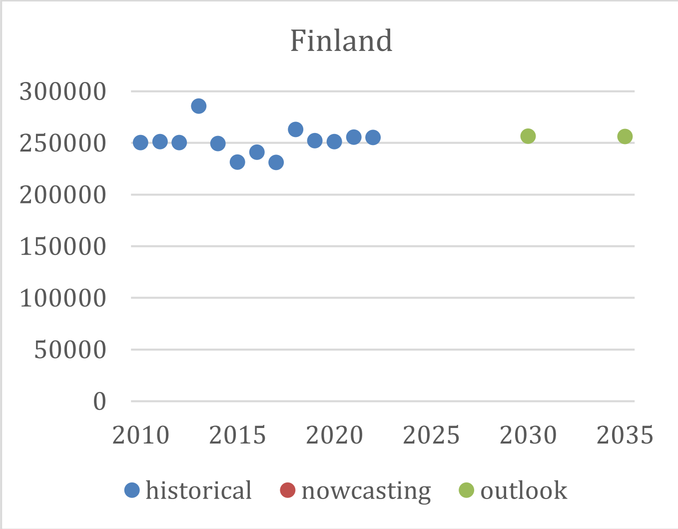
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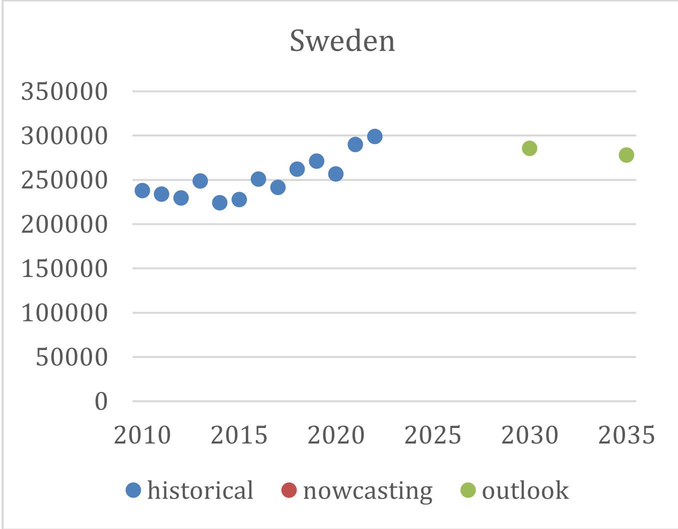
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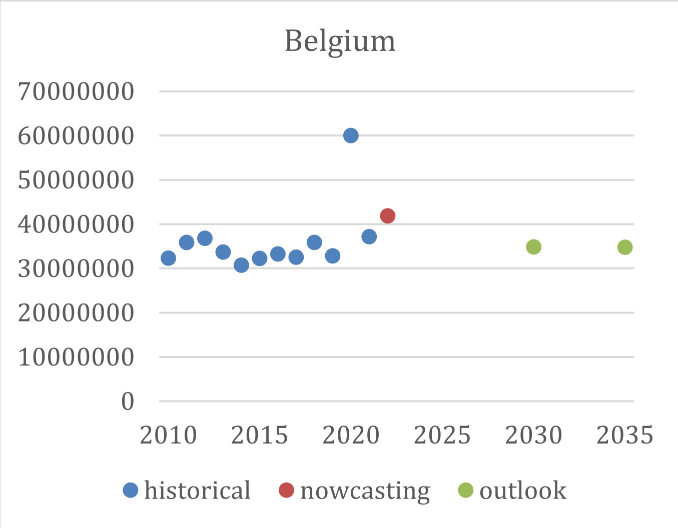
EEA consumption footprint

Table A1.2 Results of the econometric exercise

Country	△(01 Food)	△(04 Housing)	△(07 Transport)	△ln(GDP)	△ln(POP)	ln(CF,t-1)	constant
EU27	9.660	13.255	1.215	1.899	-3.970	-0.491	10.087
Belgium	-2.393	14.338	8.719	-1.899	-1.773	-0.551	9.590
Bulgaria	3.195	-3.137	6.107	2.873	-25.104	-0.466	7.285
Czechia	12.819	8.114	-4.381	0.241	-2.240	0.045	-0.753
Denmark	-7.996	12.295	-19.150	1.009	12.966	-0.327	5.393
Germany	7.219	23.809	8.908	6.513	0.600	-0.175	3.243
Estonia	5.220	17.833	9.107	0.352	-11.288	-0.722	10.835
Ireland	-6.649	-9.328	13.542	0.226	48.683	-0.762	12.198
Greece	5.633	2.081	-1.507	0.318	11.362	-0.628	11.057
Spain	3.293	11.226	-1.973	2.861	1.645	-0.335	6.002
France	7.782	17.929	15.142	4.627	14.142	-1.105	20.390
Croatia	21.337	17.485	14.605	6.334	5.061	-0.377	5.852
Italy	16.294	9.988	19.835	4.536	1.368	-0.067	1.192
Cyprus	2.971	-2.559	6.938	1.491	3.477	-0.329	5.048
Latvia	14.083	-11.416	15.960	-1.150	-4.945	-0.444	6.660
Luthuania	2.948	6.181	-1.772	1.549	1.702	-0.985	15.077
Luxembourg	-4.344	3.713	-2.040	3.131	-10.774	-0.857	13.196
Hungary	4.099	7.700	-0.009	1.259	-19.301	0.065	-1.126
Malta	-7.596	0.476	-0.764	0.714	6.551	-0.614	8.360
Netherlands	3.384	12.363	4.047	4.319	25.584	-1.145	19.894
Austria	22.749	-8.185	-7.402	-7.534	-6.814	-0.540	9.175
Poland	0.442	2.415	1.447	2.280	-34.983	-0.278	4.904
Portugal	7.104	3.056	14.574	2.748	2.545	-0.224	3.660
Romania	-7.765	-0.342	-1.341	0.953	-41.124	-0.112	1.644
Slovenia*	10.050	-	24.054	3.510	-3.951	-0.207	3.054
Slovakia	-2.612	5.640	-3.252	3.016	-29.918	-0.739	11.658
Finland	7.484	-7.380	11.195	-0.784	16.715	-1.605	26.645
Sweden	-4.844	-16.131	9.945	2.503	-13.986	-1.139	17.304
* The inclusion of the 04 Housing variable led to anomalous results. The variable has been excluded							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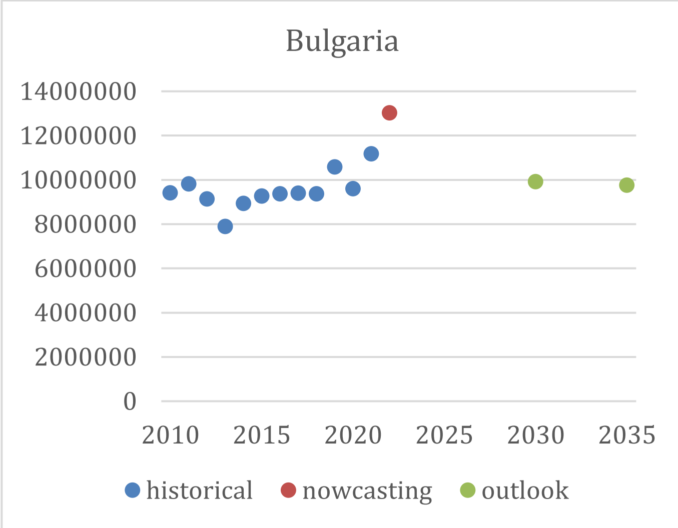
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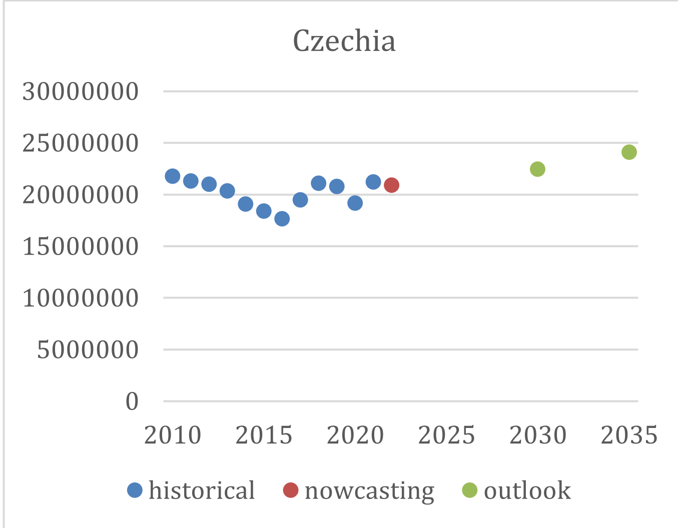
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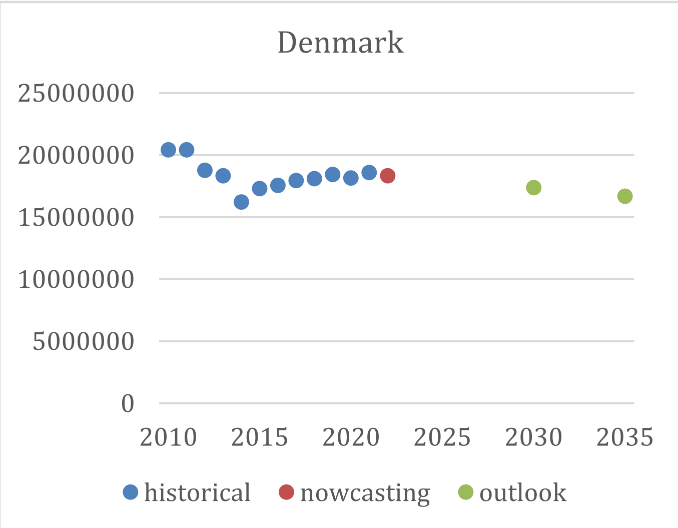
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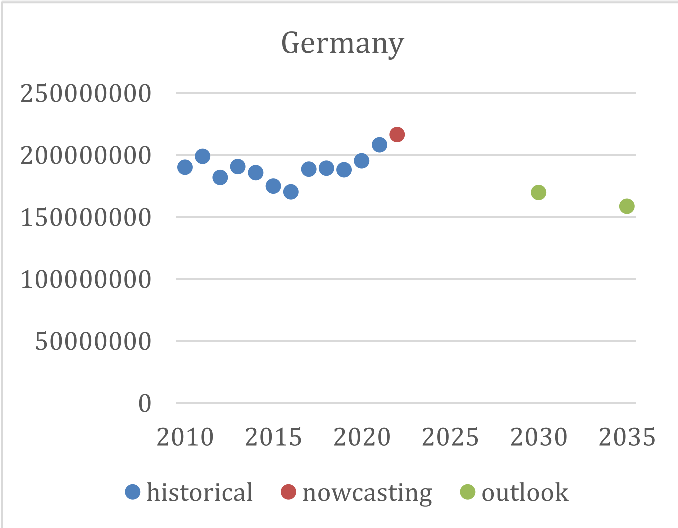
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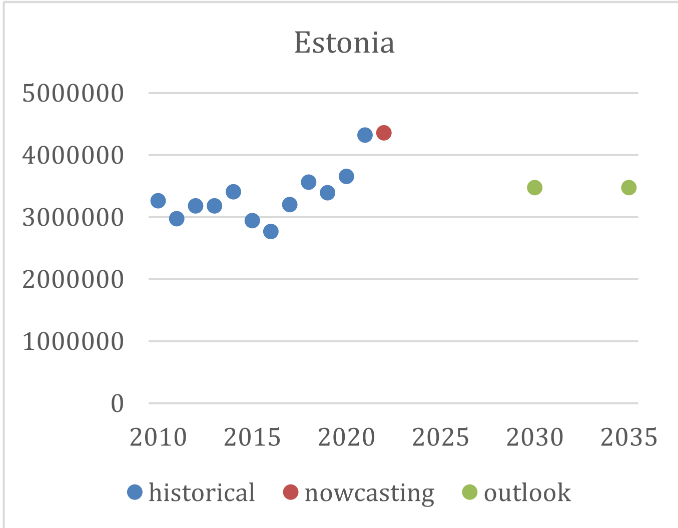
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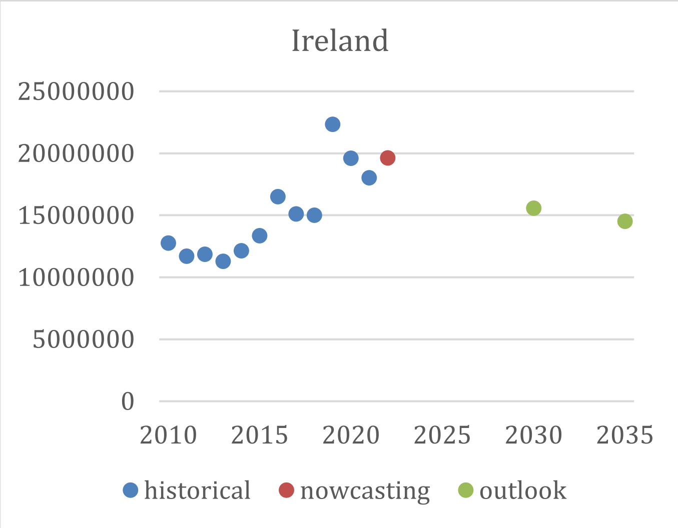
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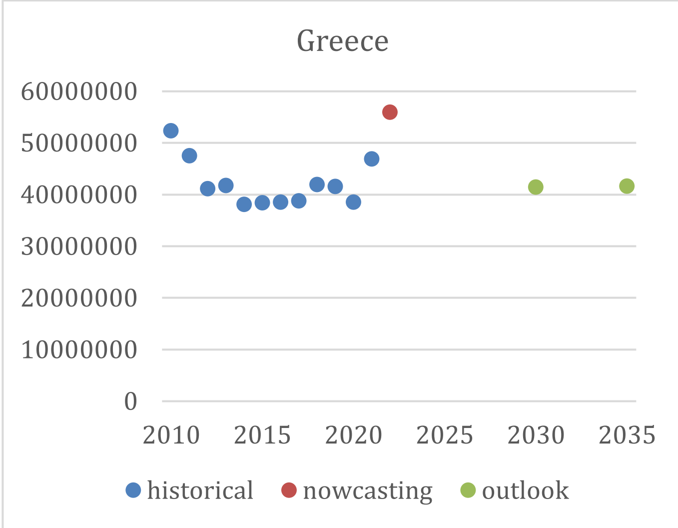
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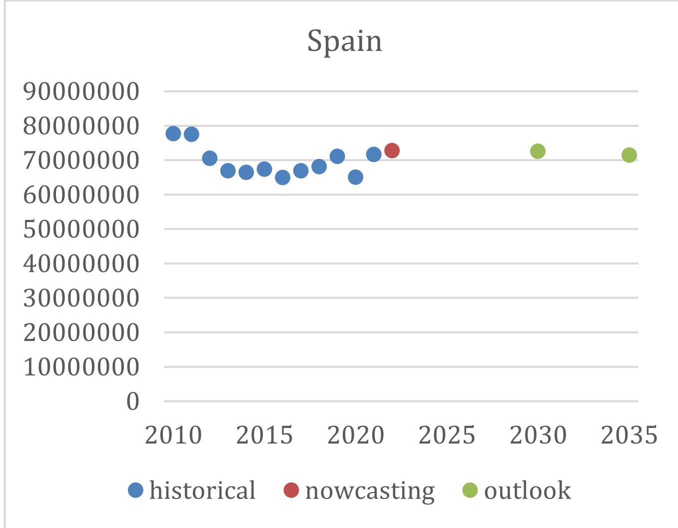
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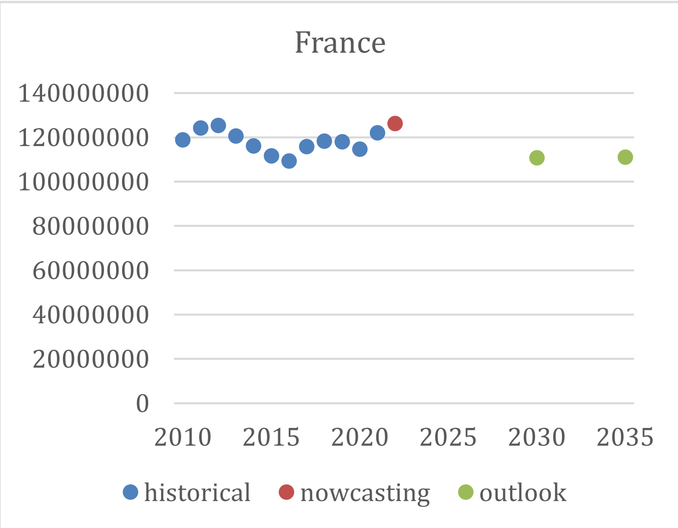
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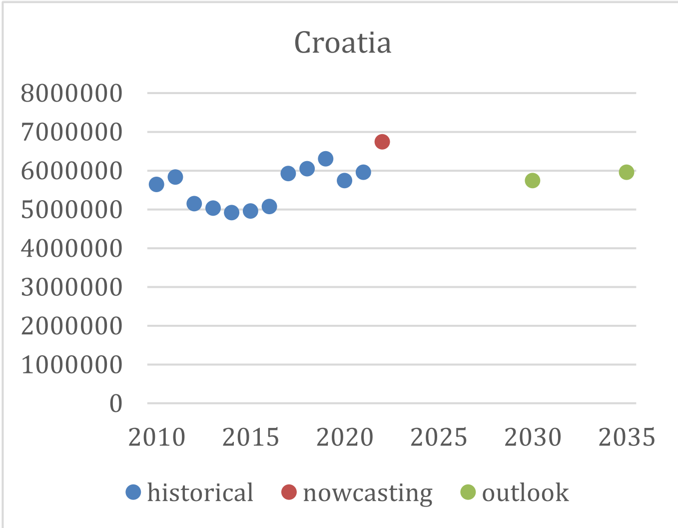
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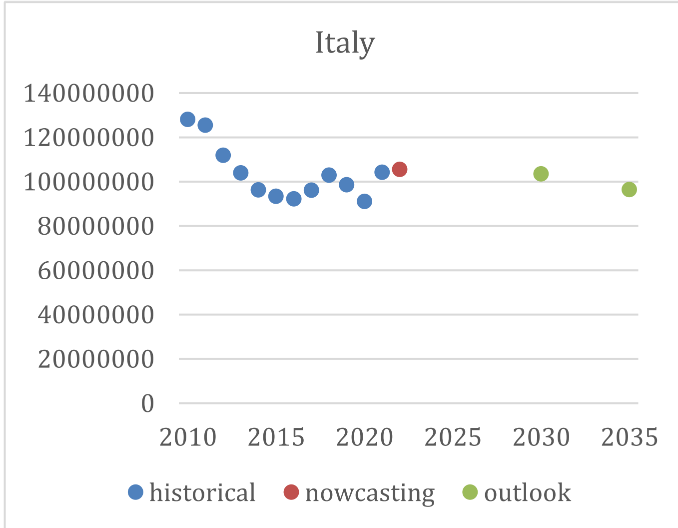
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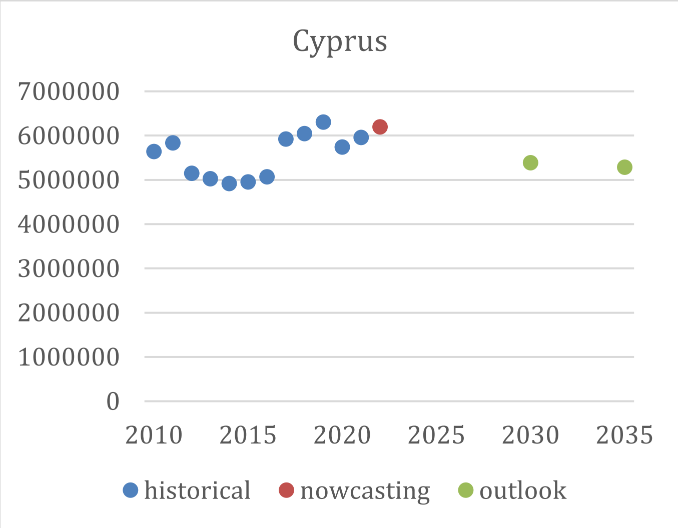
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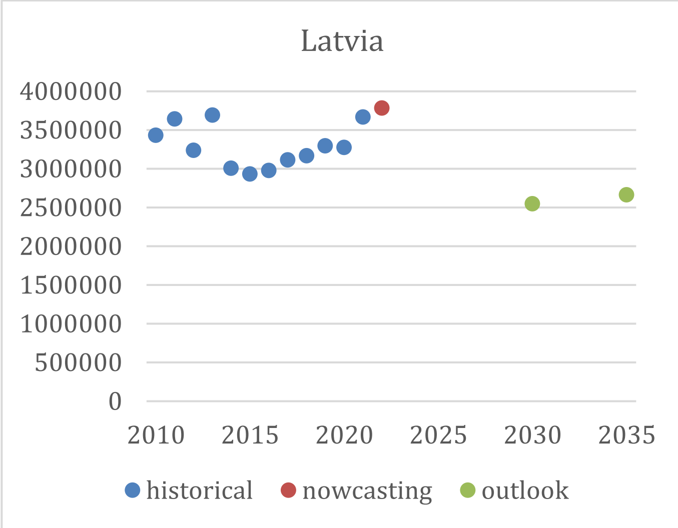
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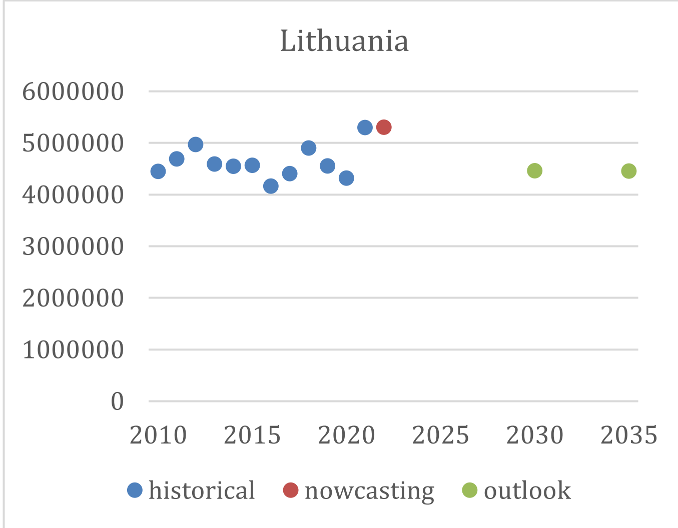
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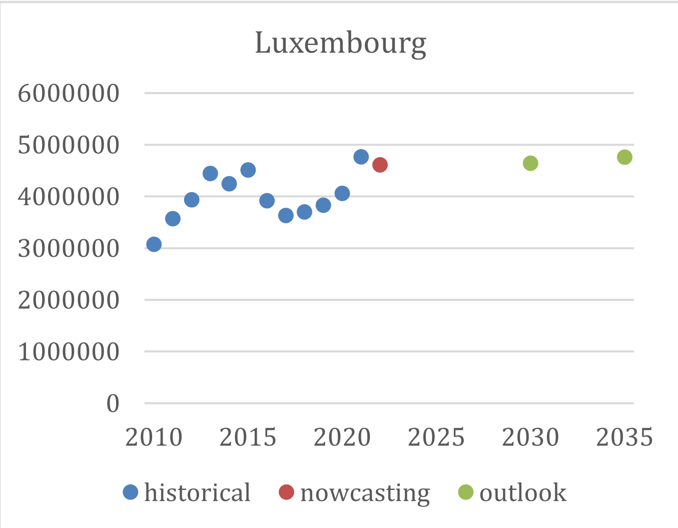
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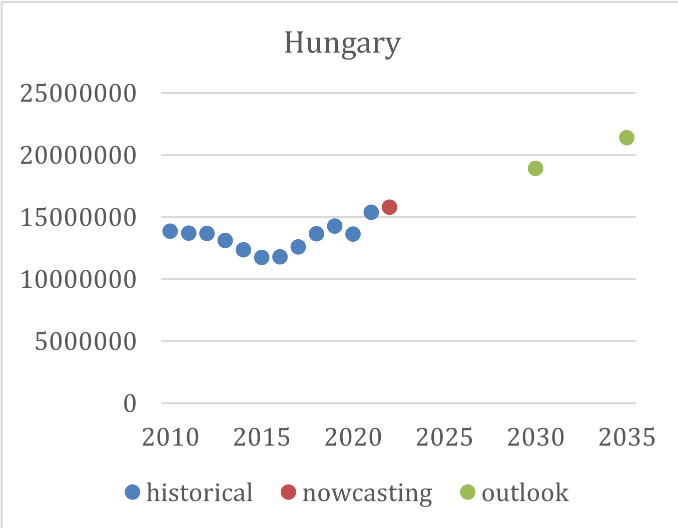
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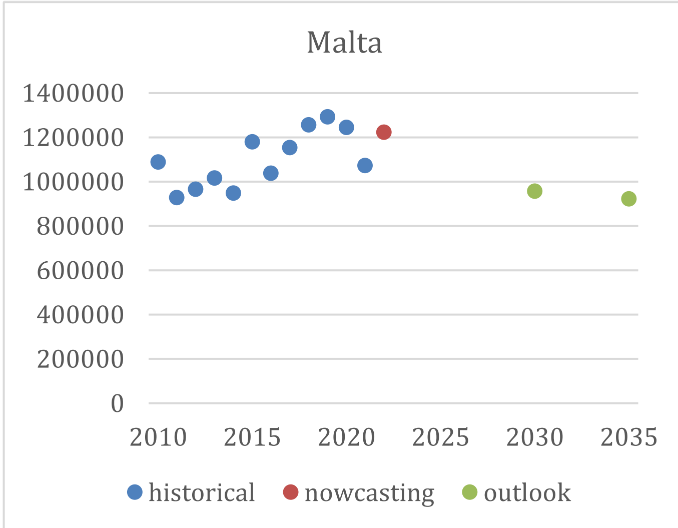
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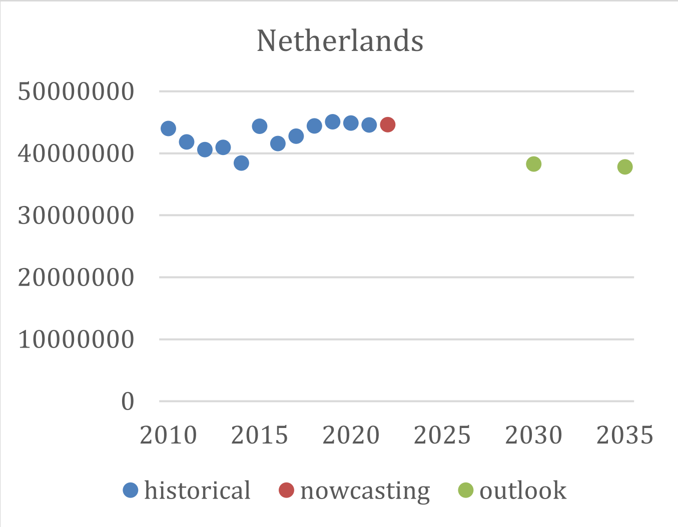
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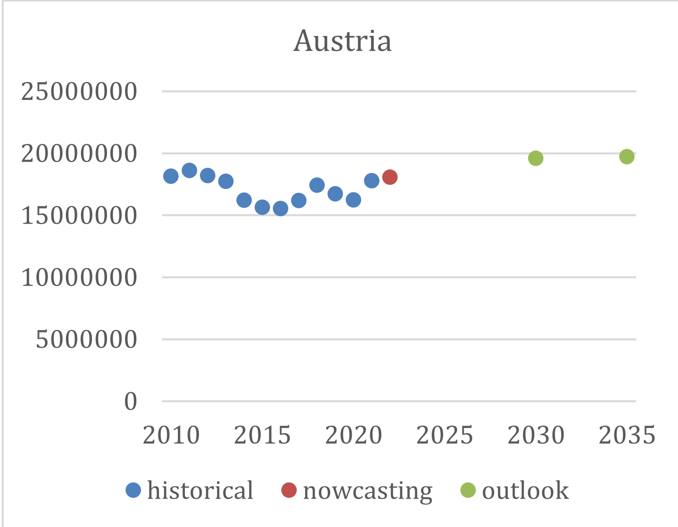
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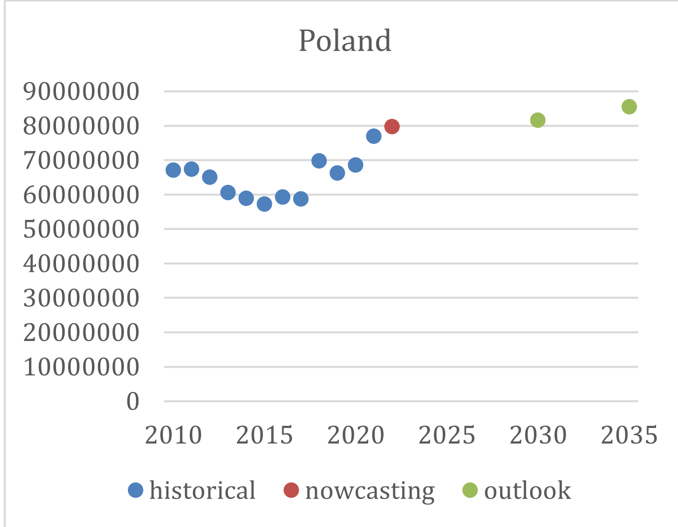
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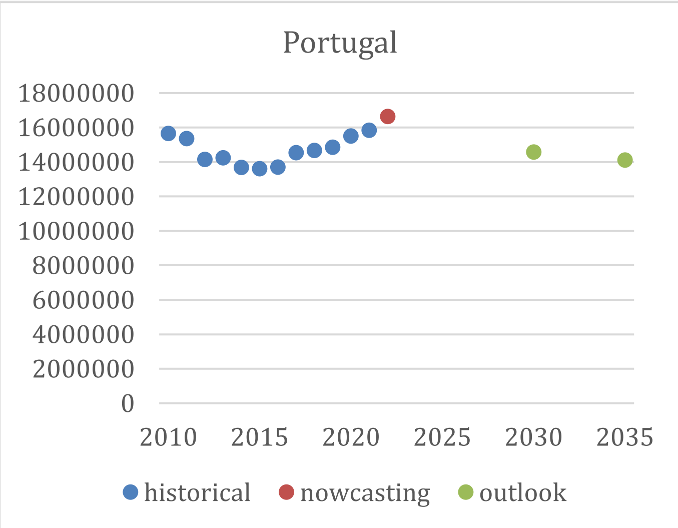
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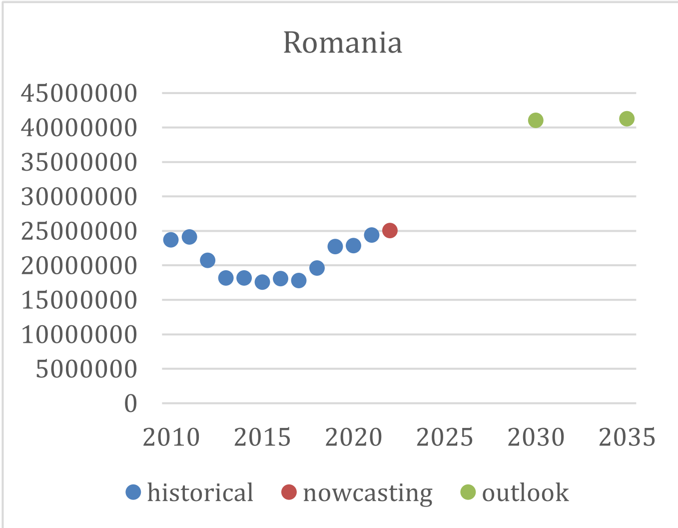
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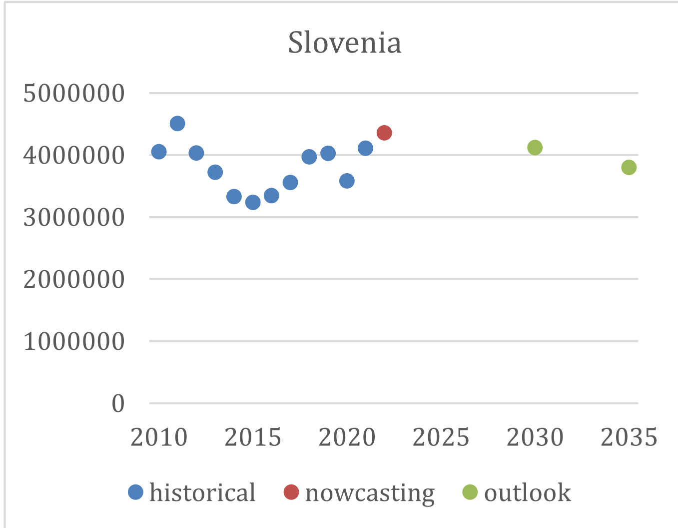
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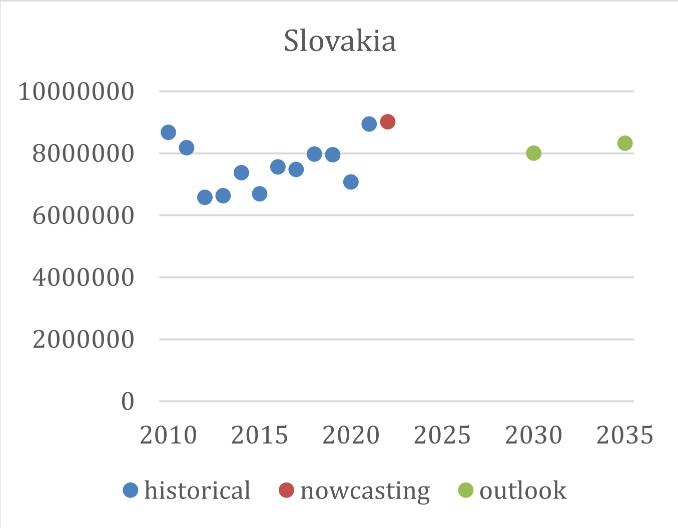
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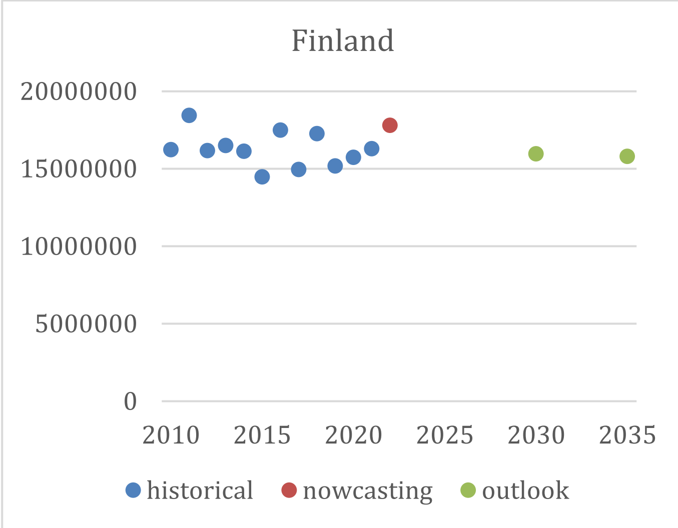
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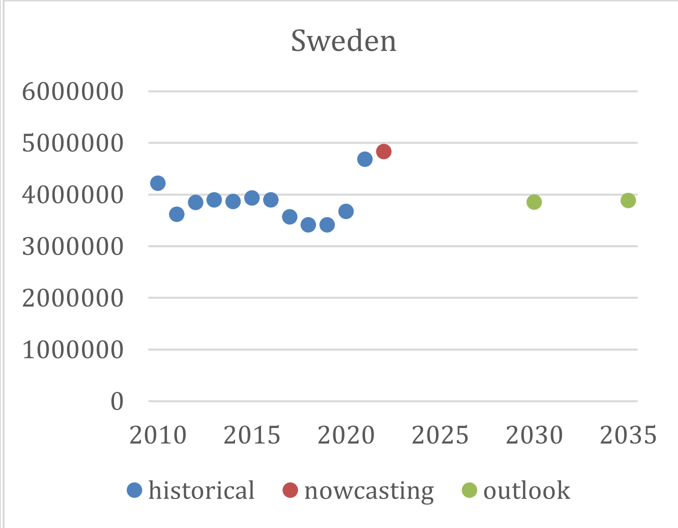
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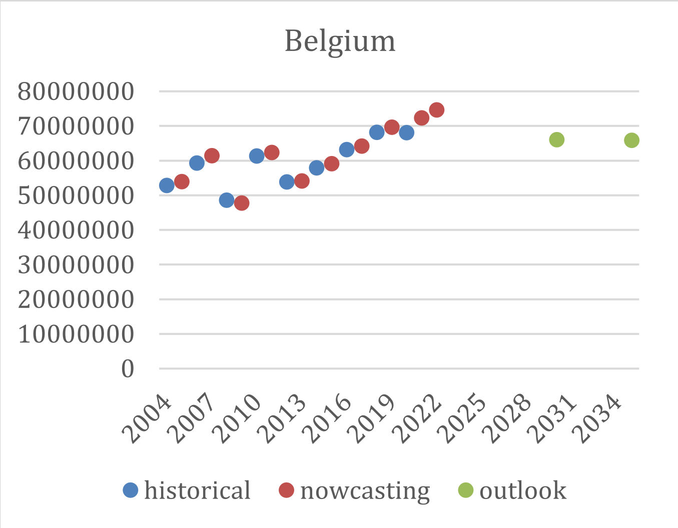
Waste generation

Table A1.3 Results of the econometric exercise

Country	△ln(GDP)	△ln(POP)	ln(WG,t-1)	constant
EU27	1.017	-3.697	-0.617	13.293
Belgium	1.474	-4.000	-0.302	5.430
Bulgaria	0.787	17.292	-0.352	6.713
Czechia	0.205	-2.032	-0.057	0.990
Denmark	1.486	0.186	-0.152	2.544
Germany	0.797	-0.139	0.041	-0.808
Estonia	0.916	-2.115	-0.458	7.682
Ireland	1.441	10.005	-0.285	4.560
Greece	1.527	6.418	-0.075	1.357
Spain	1.787	-1.534	-0.027	0.486
France	1.104	-4.021	-0.273	5.377
Croatia	0.790	-4.745	-0.256	3.892
Italy	0.399	-0.309	-0.180	3.418
Cyprus	0.991	-1.407	-0.510	7.406
Latvia	1.115	2.741	-0.322	4.719
Luthuania	1.103	4.544	-0.504	7.920
Luxembourg	0.189	-7.718	-0.565	9.203
Hungary	1.434	11.928	-0.339	5.650
Malta	0.058	6.782	-0.027	0.308
Netherlands	1.794	13.665	-0.243	4.449
Austria	0.136	9.695	0.020	-0.389
Poland	0.819	-14.682	-0.273	5.134
Portugal	0.891	4.924	-0.268	4.451
Romania	0.830	26.278	-0.208	4.096
Slovenia	2.293	12.579	-0.248	3.806
Slovakia	0.759	-24.194	-0.293	4.753
Finland	1.816	2.925	-0.123	2.267
Sweden	1.415	3.172	-0.165	3.057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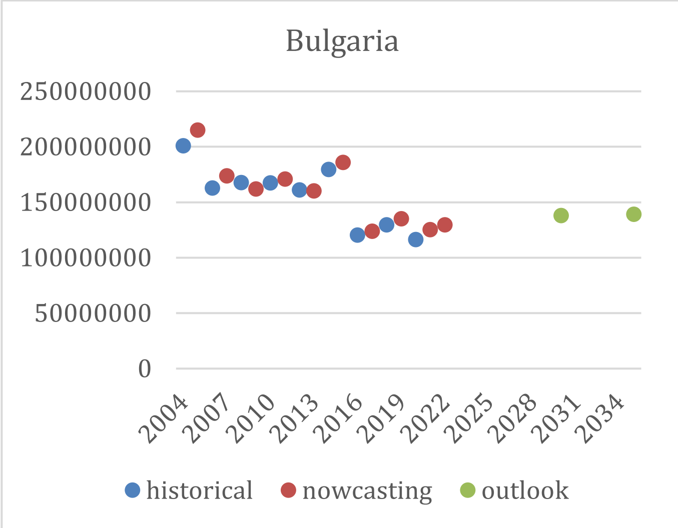
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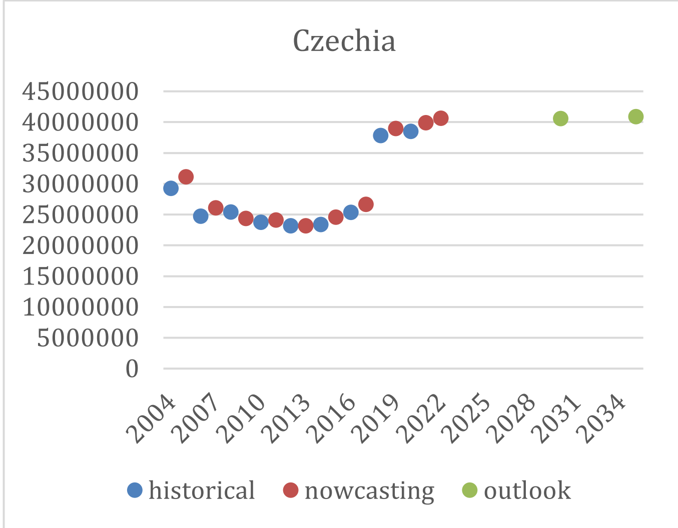
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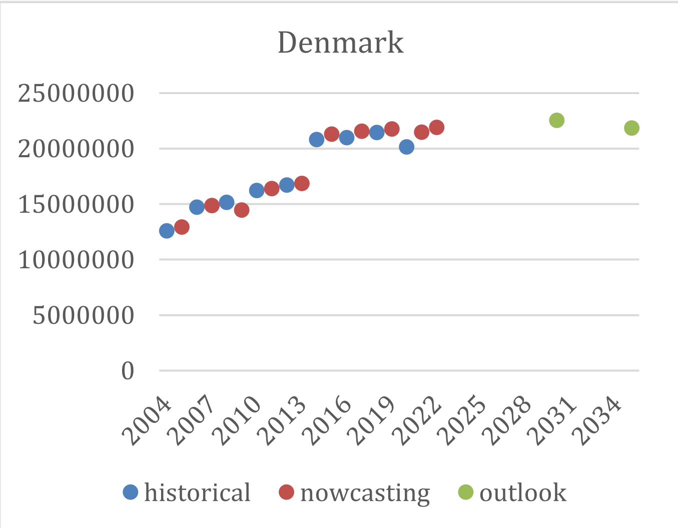
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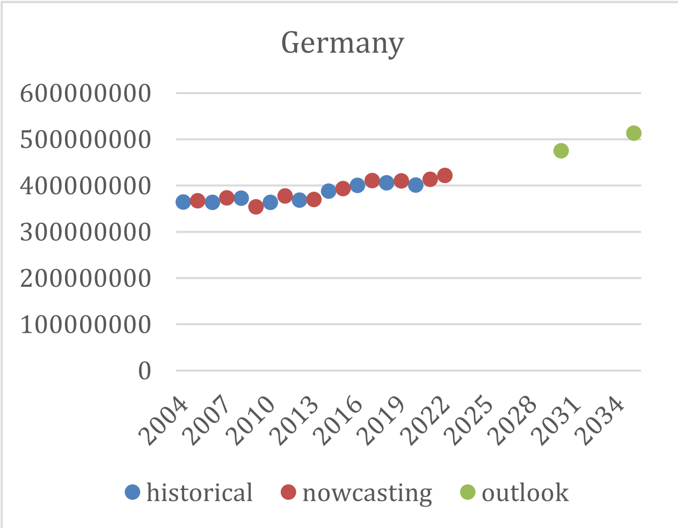
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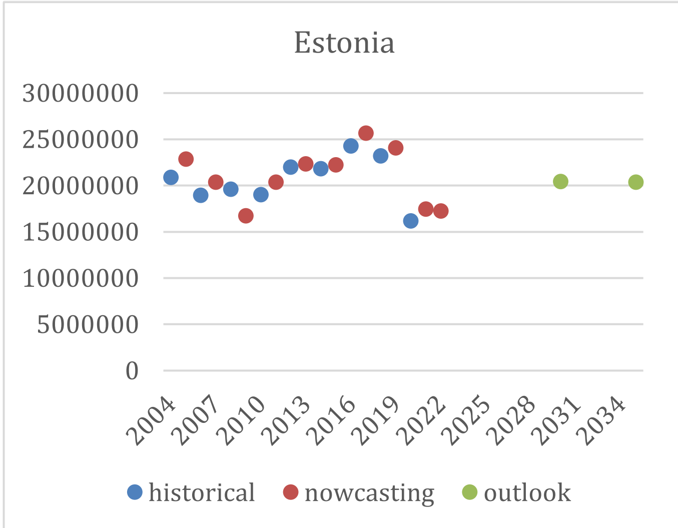
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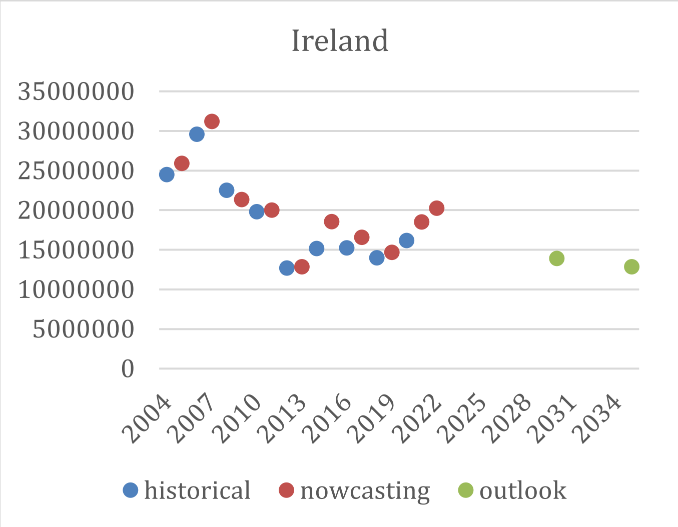
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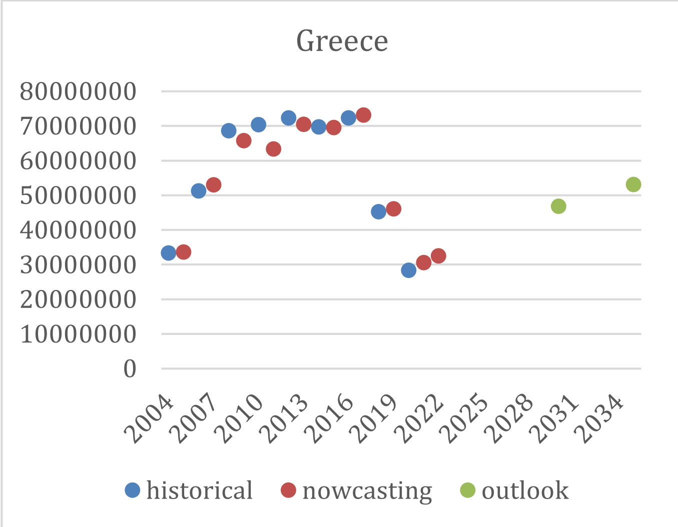
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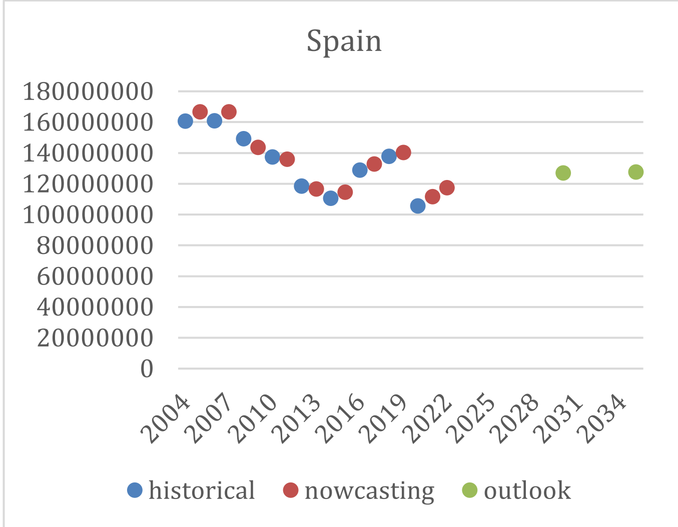
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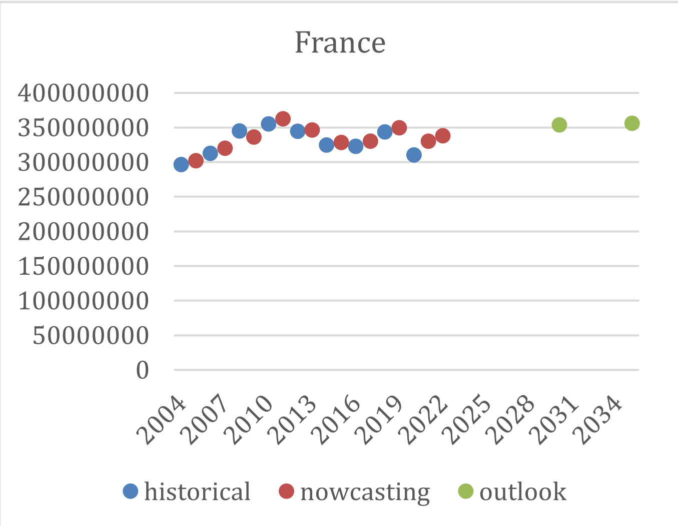
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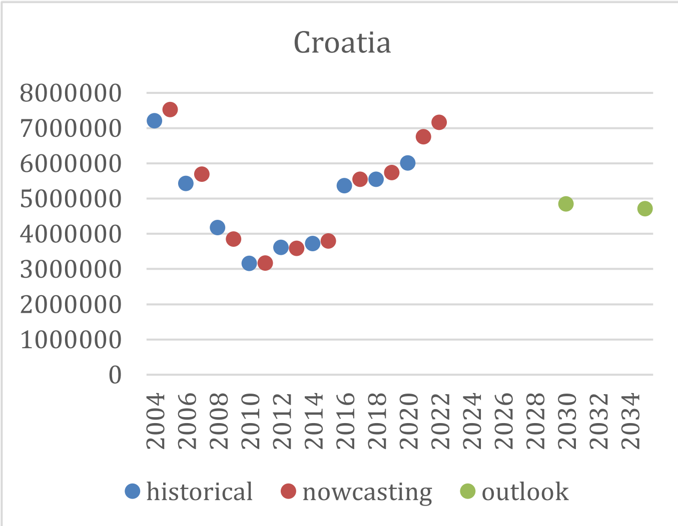
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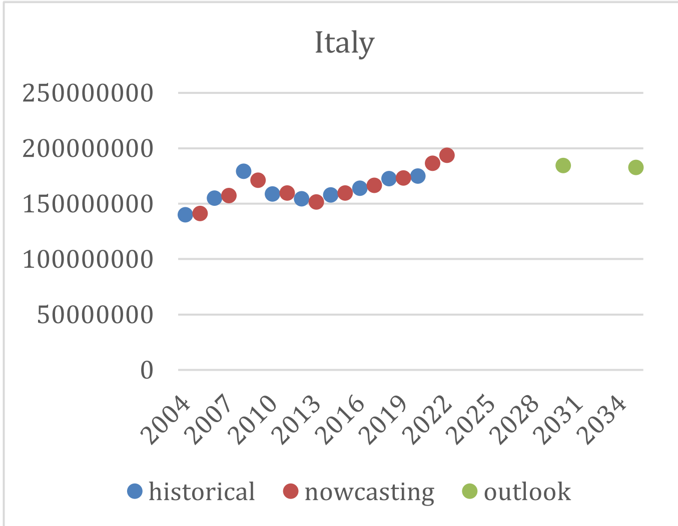
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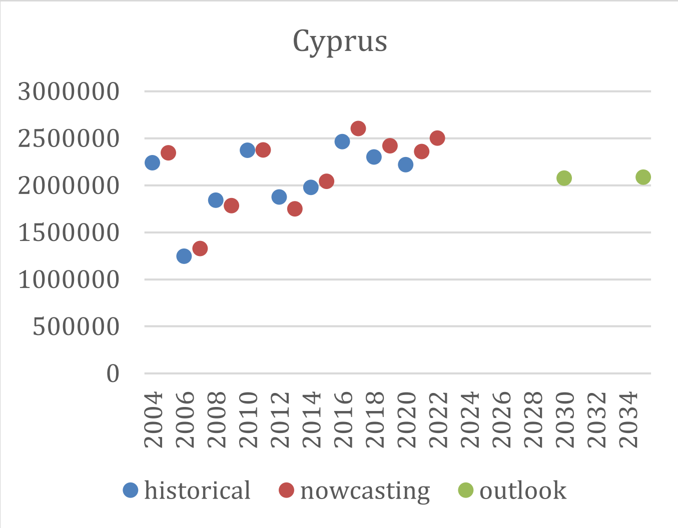
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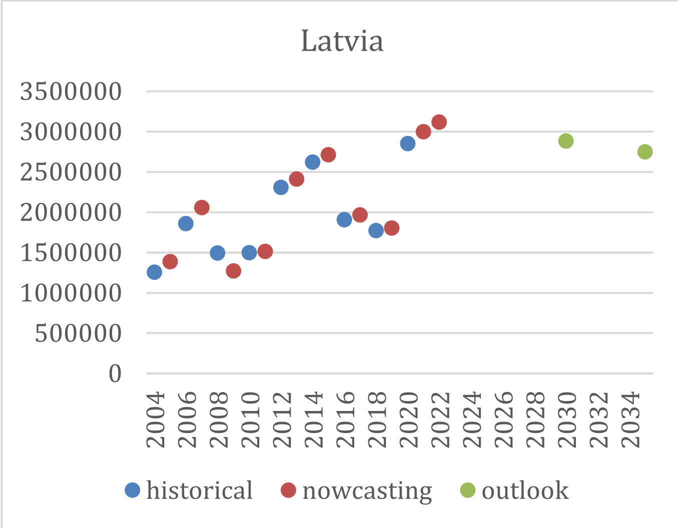
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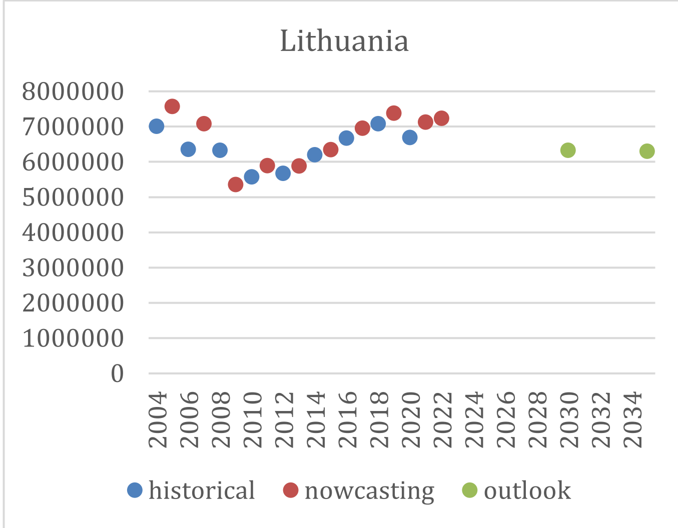
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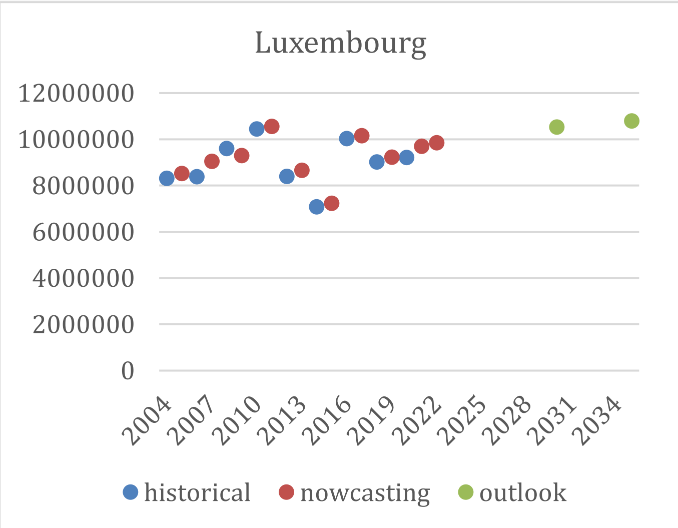
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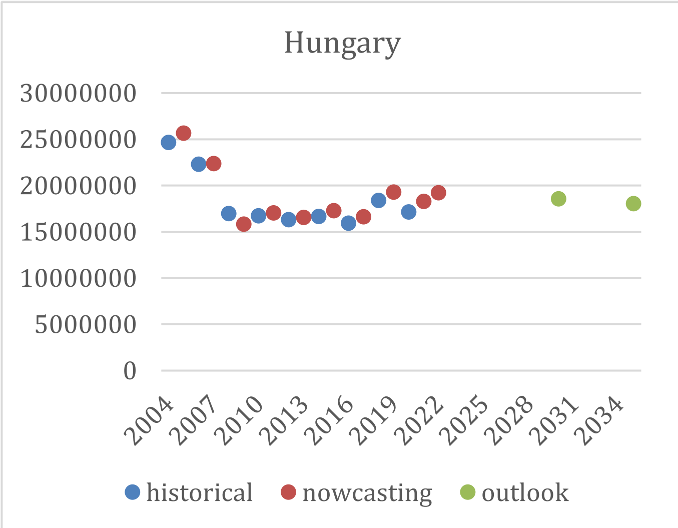
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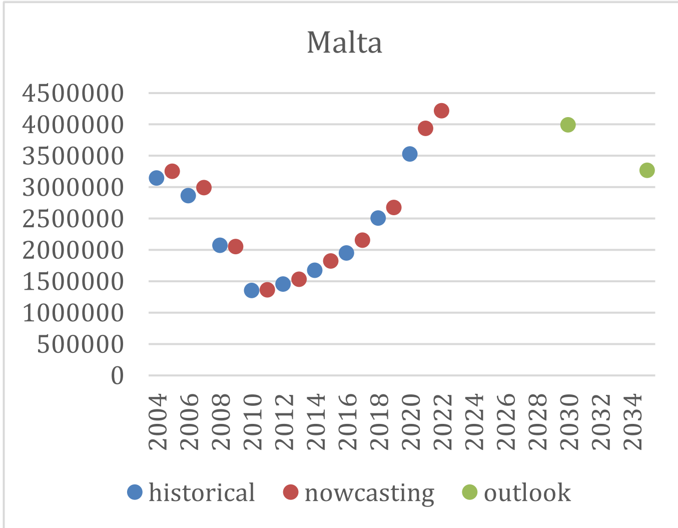
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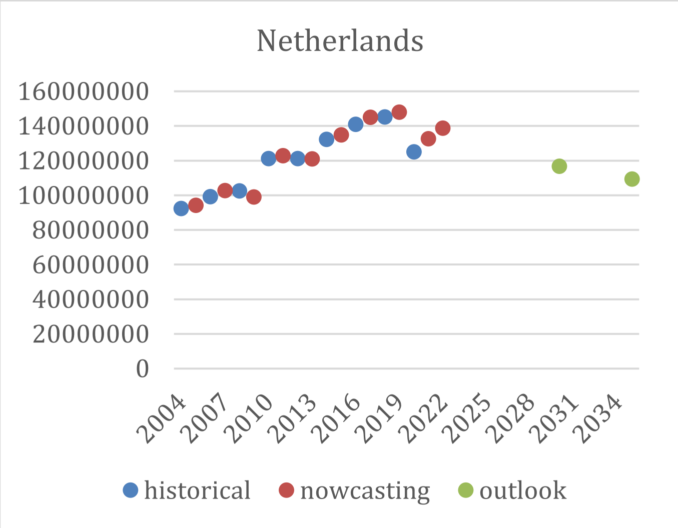
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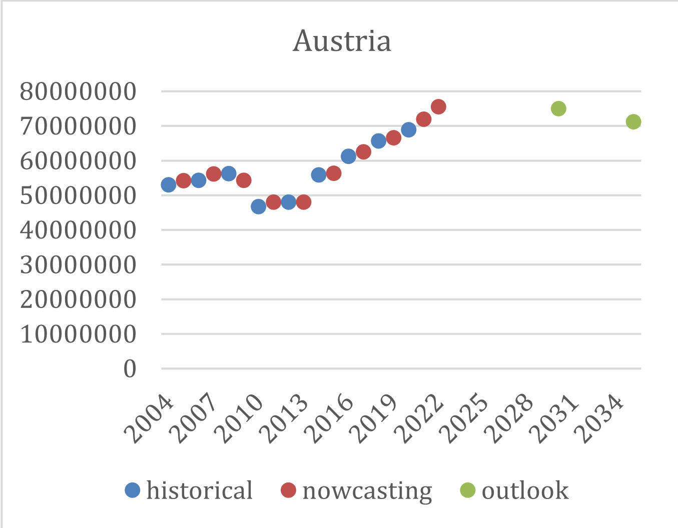
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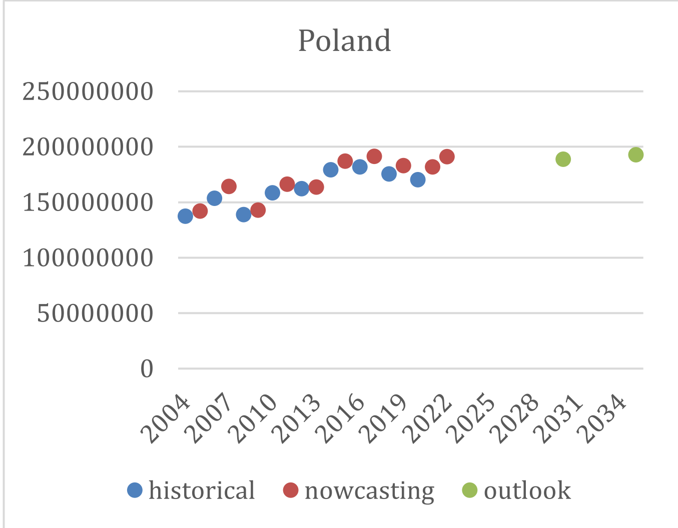
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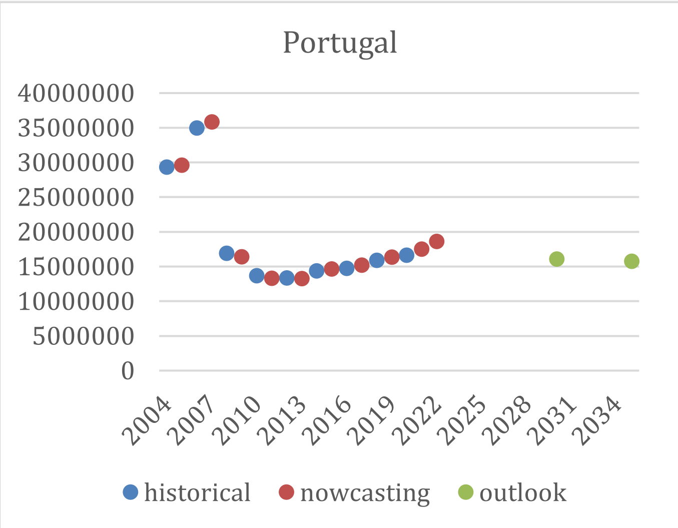
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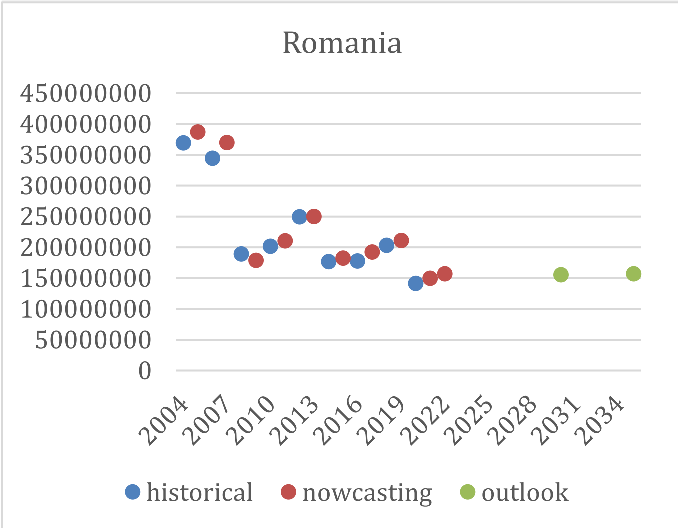
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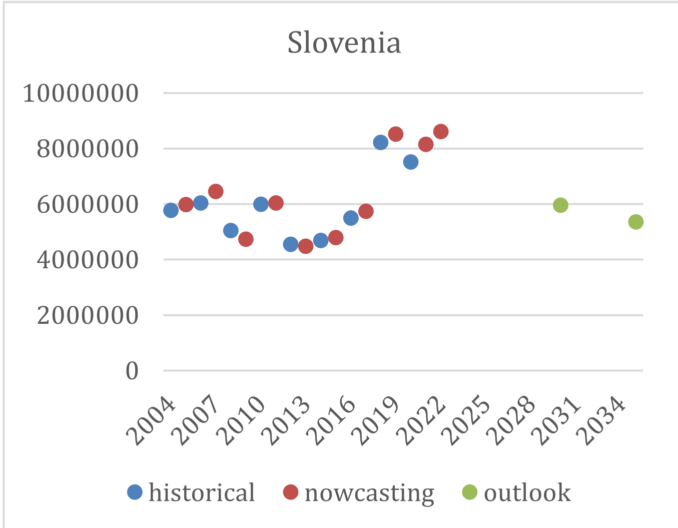
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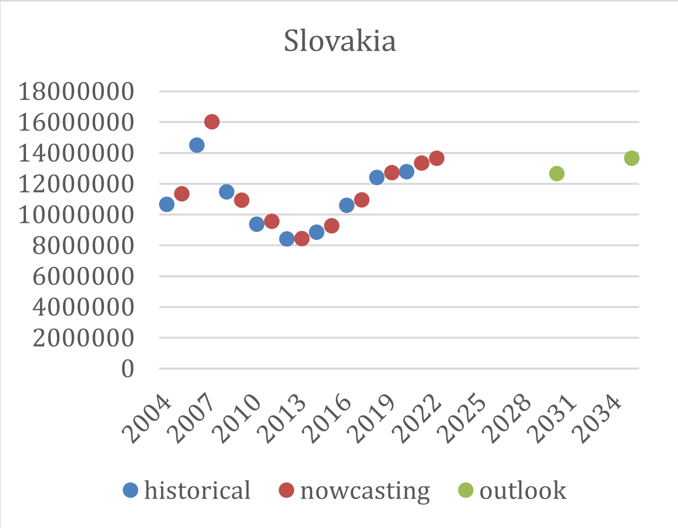
2004 2007 2010 2013 2016 2019 2022 2025 2028 2031 2034
historical nowcasting outlook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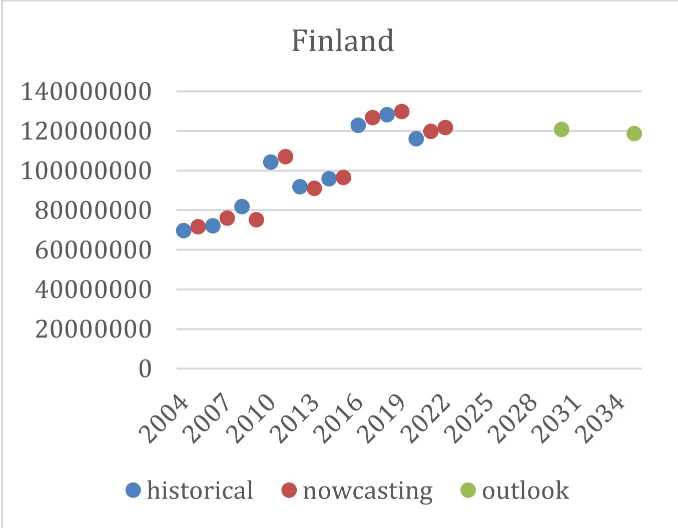
2034
historical
nowcasting
outlook


Finland
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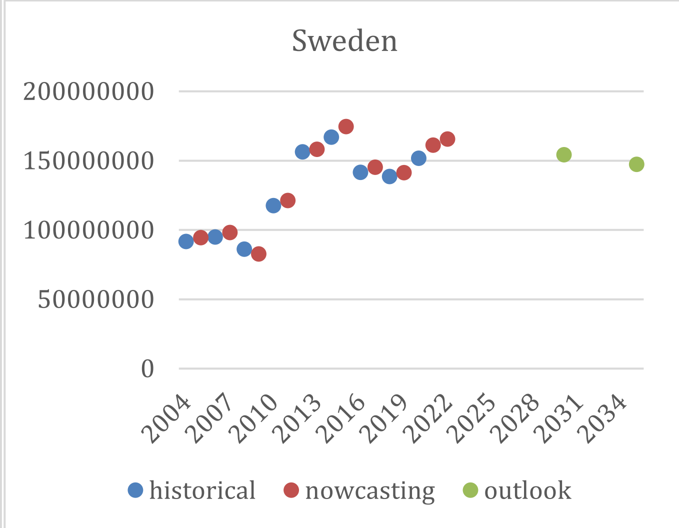
historical
nowcasting
outlook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2004
2007
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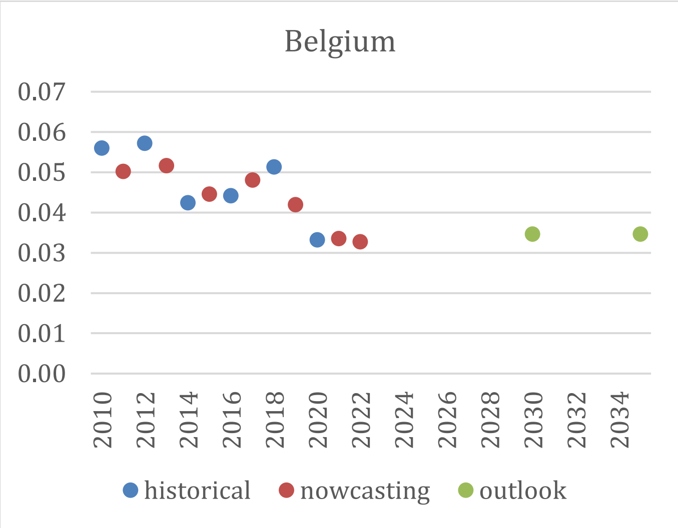
2034
historical
nowcasting
outlook

Diversion of waste from landfills

Table A1.4 Results of the econometric exercise

Country	△ln(GDP)	△ln(POP)	LD,t-1	constant
EU27	0.013	-1.403	0.050	-0.015
Belgium	0.053	-0.055	-0.170	0.005
Bulgaria	-0.338	22.662	-0.287	0.318
Czechia	-0.189	1.224	-0.355	0.072
Denmark	-0.066	-0.090	-0.128	0.001
Germany	0.198	0.662	-0.861	0.077
Estonia	-0.340	0.642	-0.467	0.370
Ireland	-0.297	-3.317	-0.871	0.150
Greece	-0.059	2.892	-0.163	0.083
Spain	-0.422	-4.552	-0.132	0.037
France	-0.167	0.975	-0.242	0.041
Croatia	0.054	-0.014	0.091	-0.056
Italy	0.050	-0.453	-0.019	-0.006
Cyprus	-0.192	0.347	-0.196	0.121
Latvia	-0.373	-5.748	-0.416	0.041
Luthuania	0.684	0.837	-0.083	-0.025
Luxembourg	0.811	1.392	-0.456	-0.015
Hungary	-0.815	-2.766	-0.122	0.045
Malta	-0.433	-1.654	-0.658	0.399
Netherlands	-0.036	0.027	-0.577	0.015
Austria	0.112	-0.528	-0.572	0.051
Poland	0.343	-1.959	-0.307	0.057
Portugal	-0.284	-0.102	-0.300	0.073
Romania	0.113	22.485	-0.591	0.405
Slovenia	-0.143	-0.155	-0.358	0.015
Slovakia	0.106	-0.426	-0.081	0.018
Finland	-0.123	12.726	-0.793	0.031
Sweden	0.127	-1.035	-0.369	0.031


Belgium
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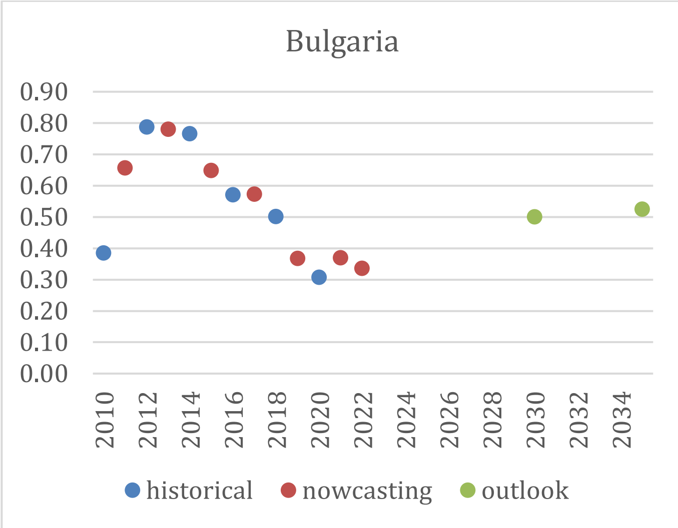
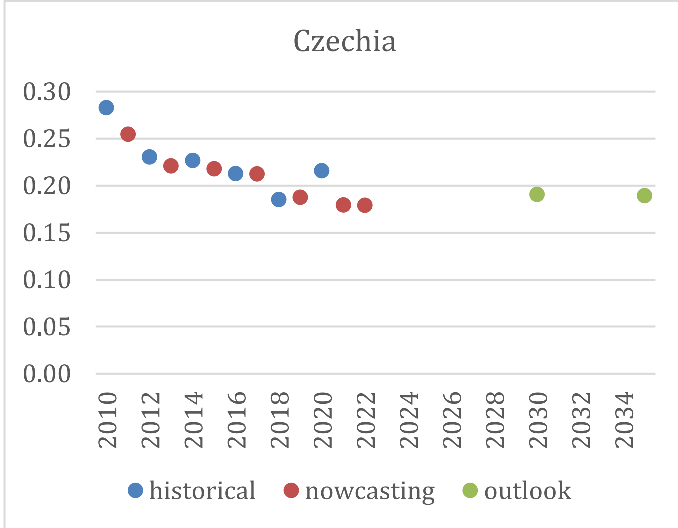
0.06
0.05
0.04
0.03
0.02
0.01
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical
nowcasting
outlook


Bulgaria
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical
nowcasting
outlook


Czechia
0.30
0.25
0.20
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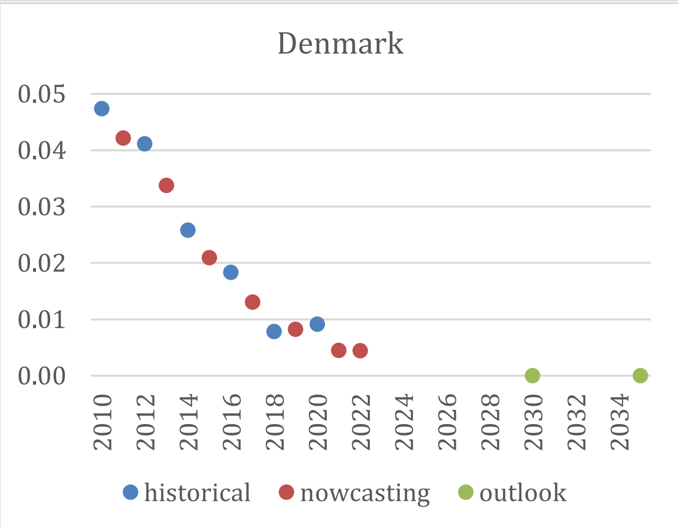
0.10
0.05
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical
nowcasting
outlook


Denmark
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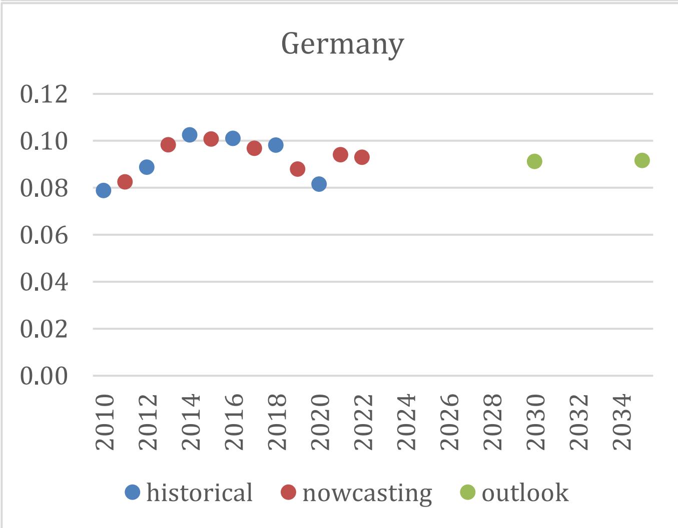
0.04
0.03
0.02
0.01
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical
nowcasting
outlook


Germany
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0.10
0.08
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0.04
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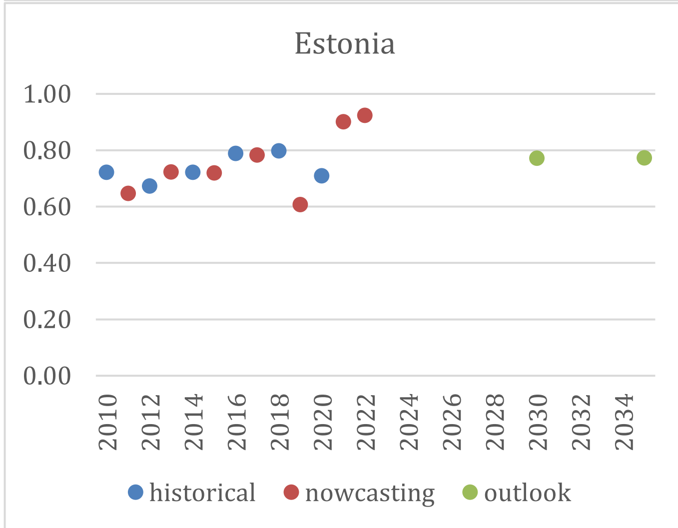
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical
nowcasting
outlook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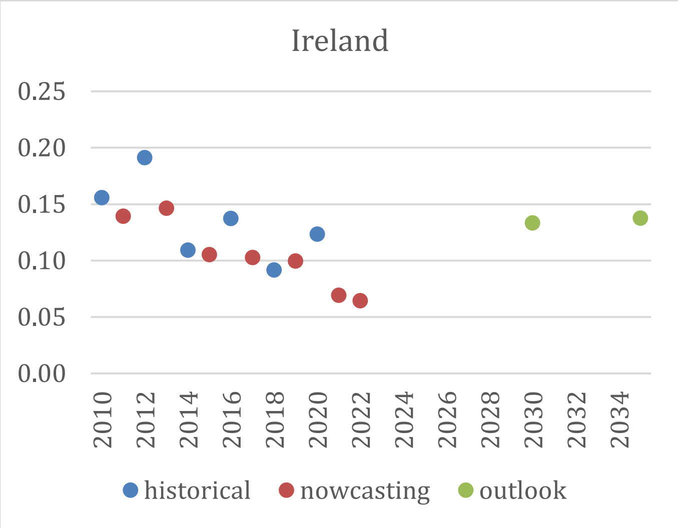
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical
nowcasting
outlook


Ireland
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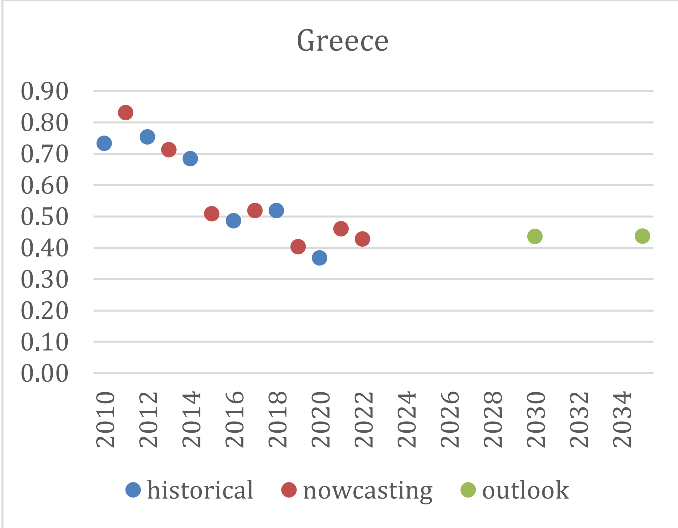
0.05
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook


Greece
0.90
0.80
0.70
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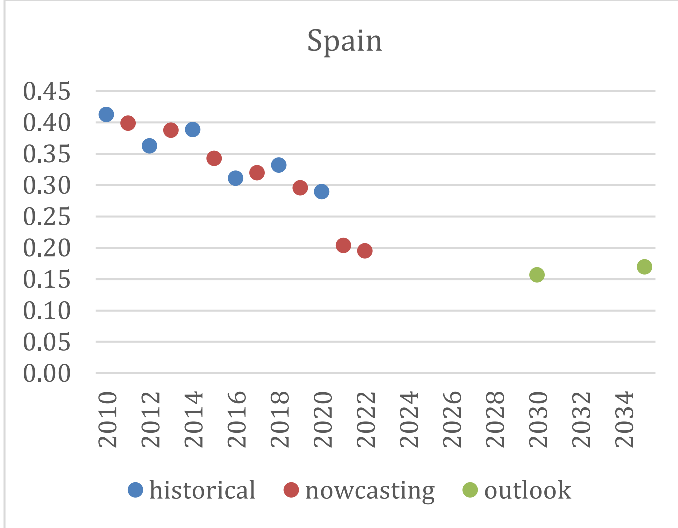
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook


Spain
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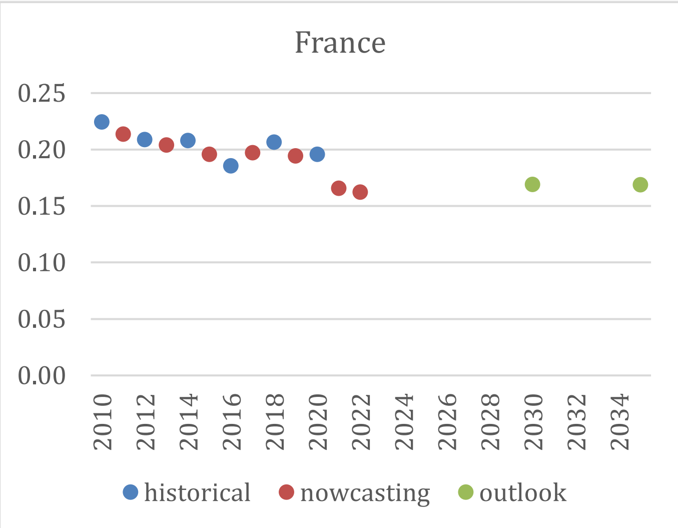
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook


France
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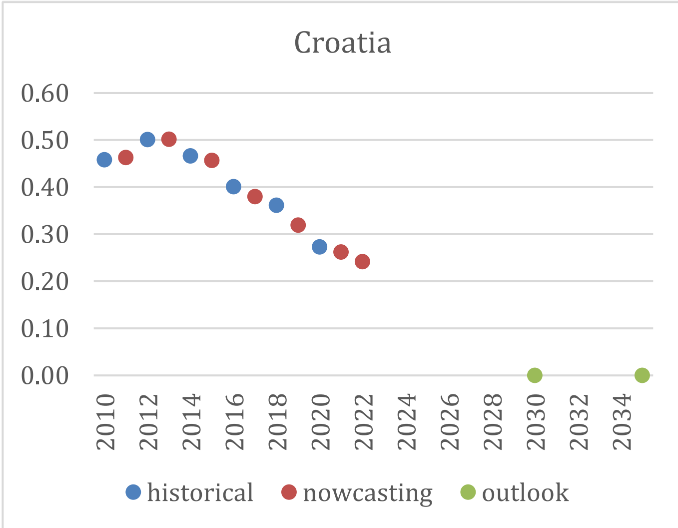
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook


Croatia
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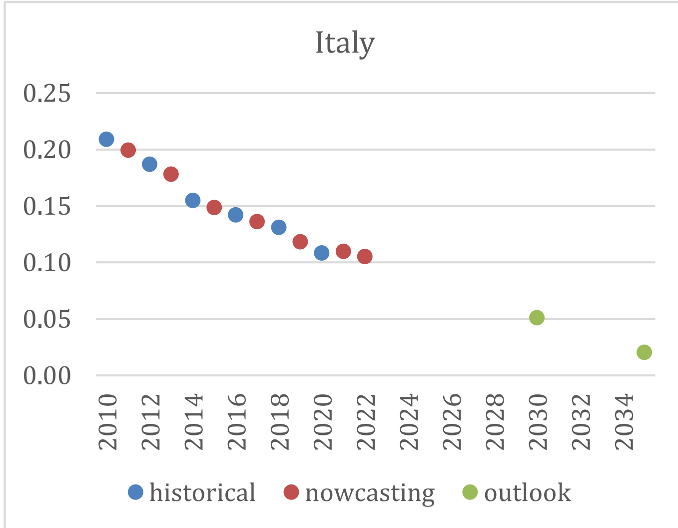
historical nowcasting outlook


Italy
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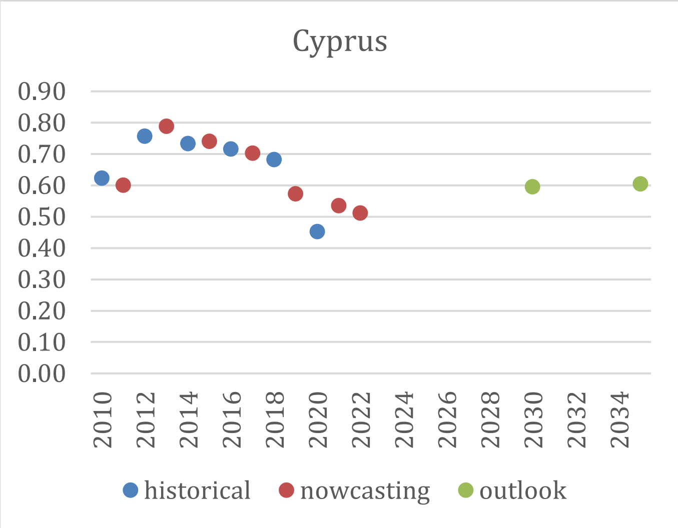
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook


Cyprus
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0.70
0.60
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2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
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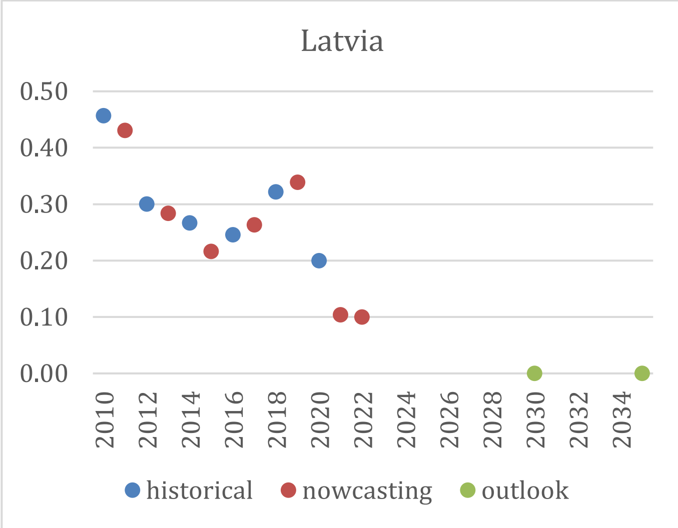
Latvia
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2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
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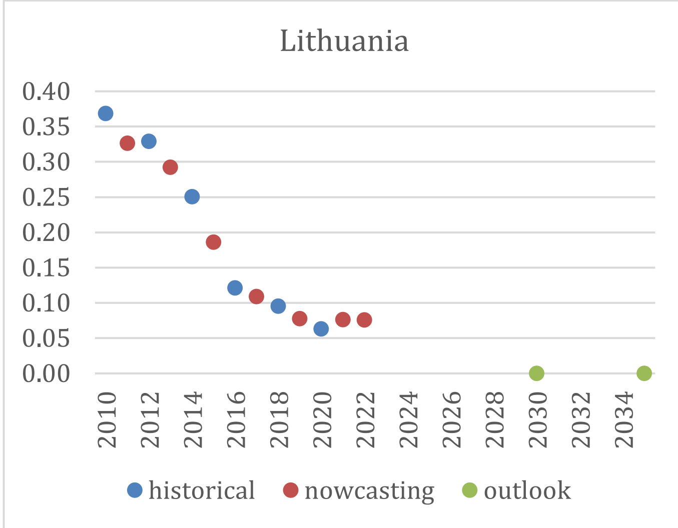
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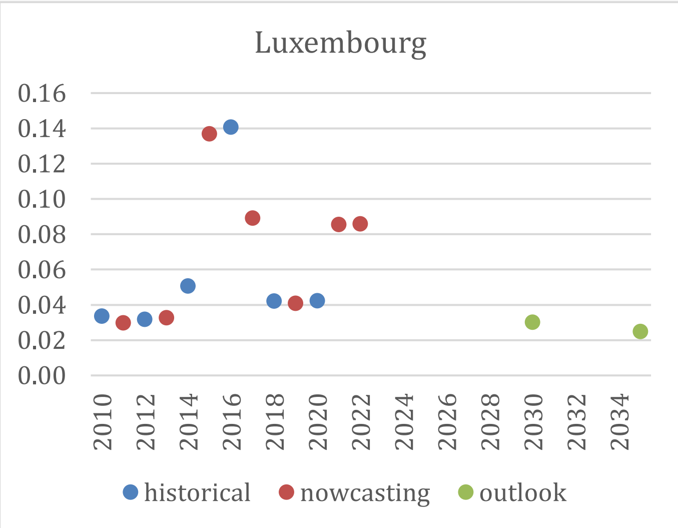
Luxembourg
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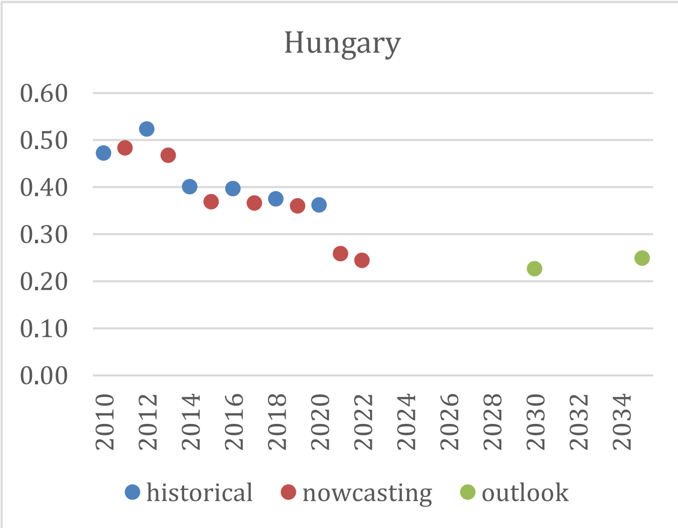
Hungary
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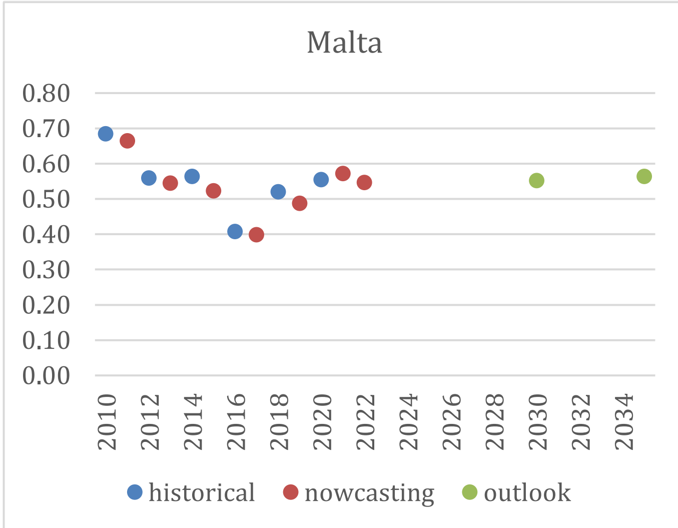
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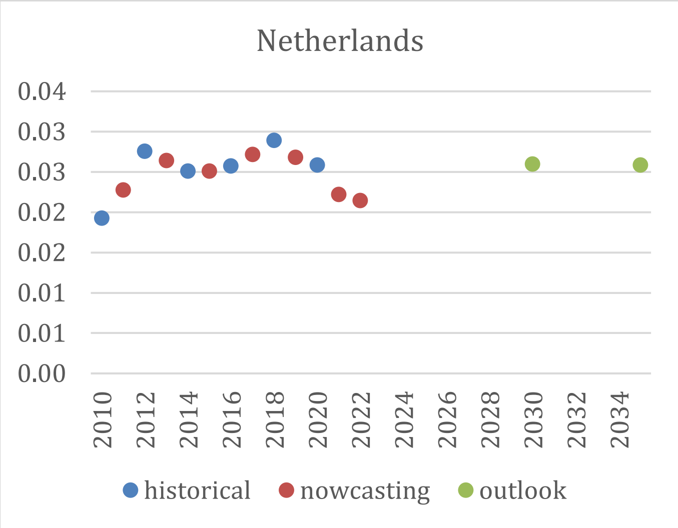
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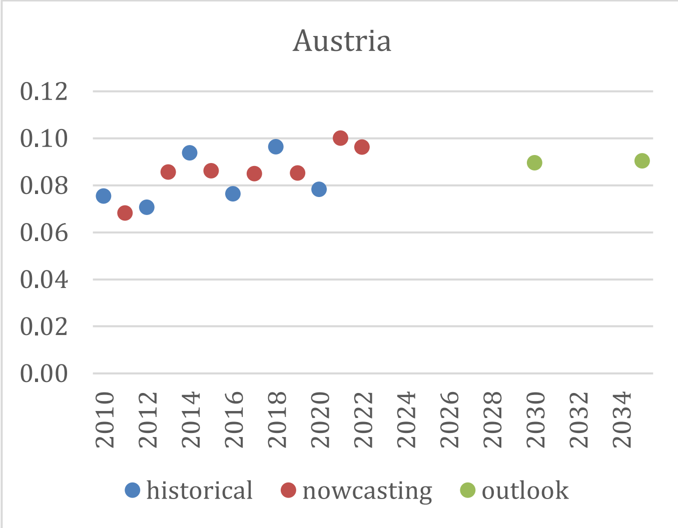
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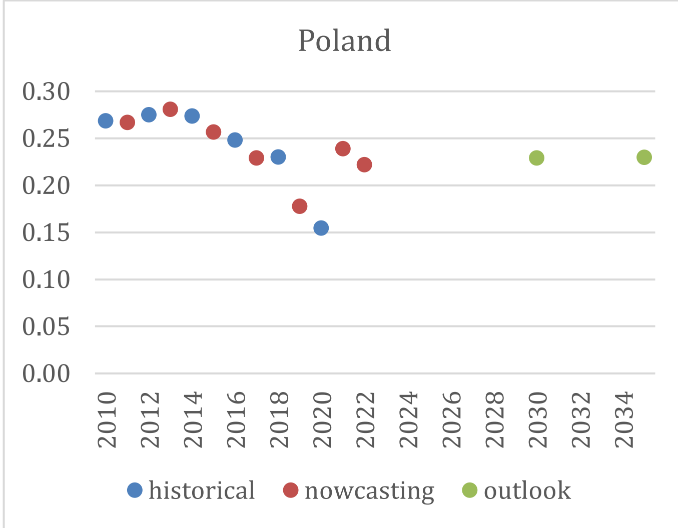
Poland
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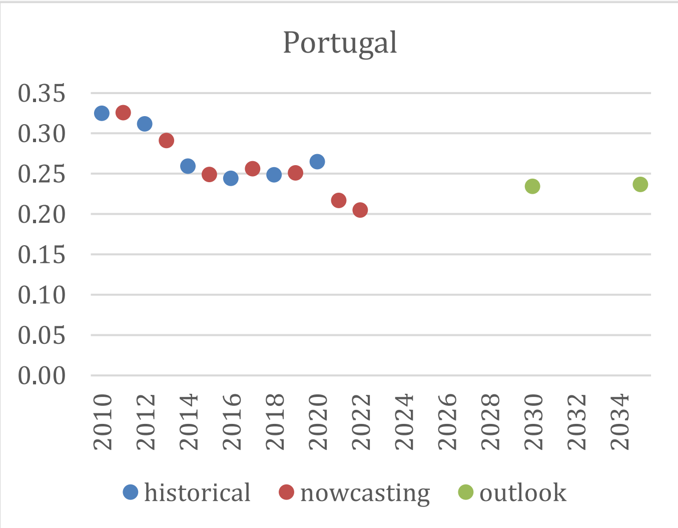
outlook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2016
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2020
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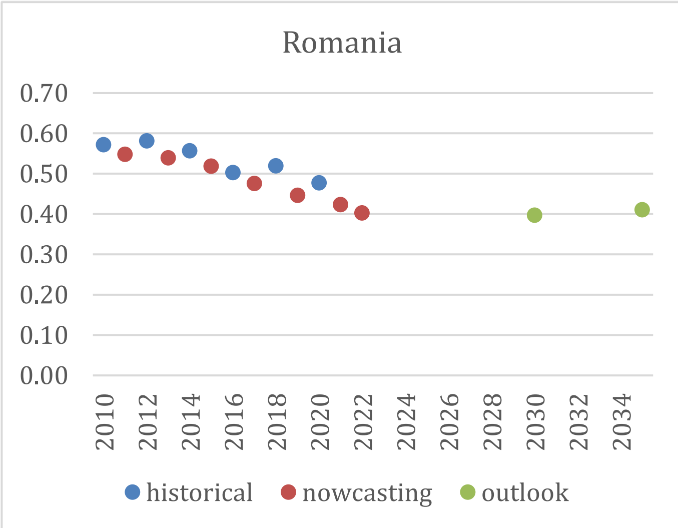
Romania
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0.10
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2016
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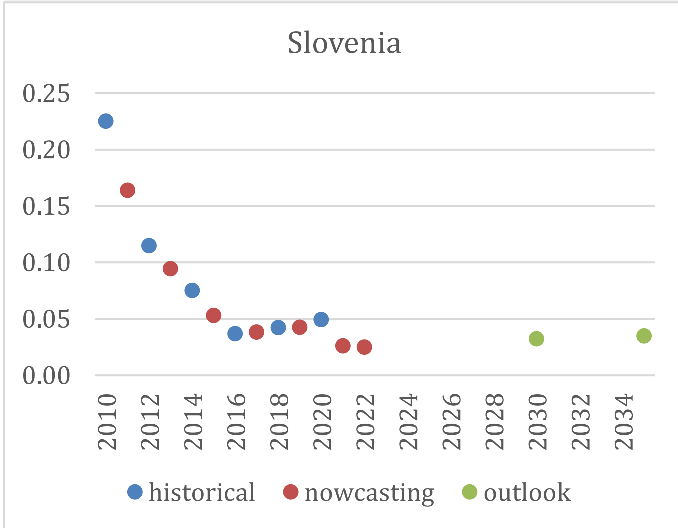
historical
nowcasting
outlook


Slovenia
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0.15
0.10
0.05
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2012
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2016
2018
2020
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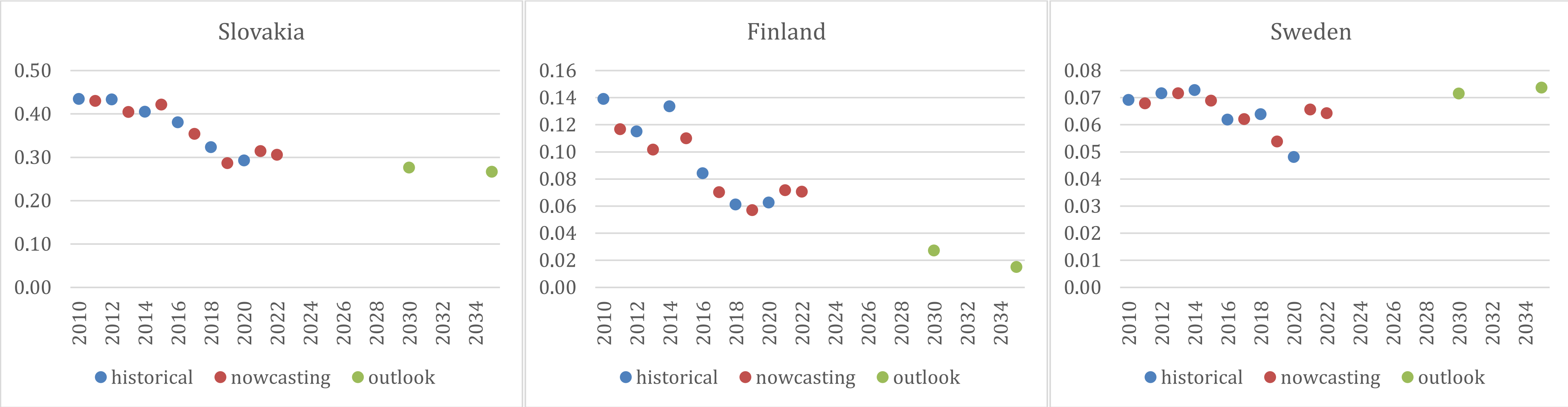
historical
nowcasting
outlook


Slovakia
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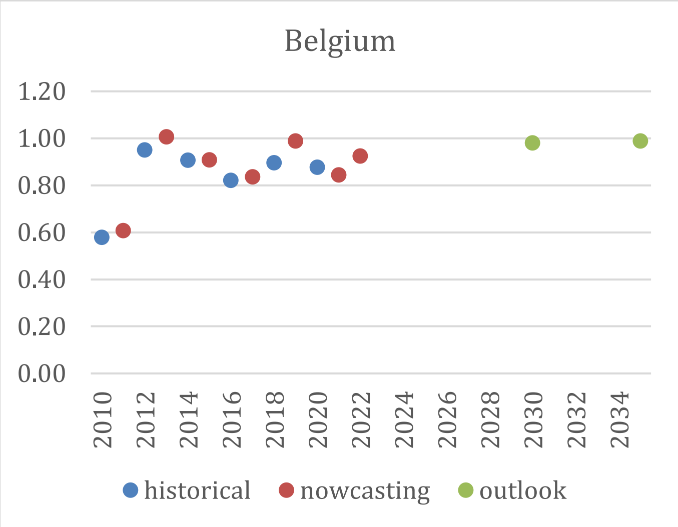
0.40
0.30
0.20
0.10
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook
Finland
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook
Sweden
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook

Waste recycling

Table A1.5 Results of the econometric exercise

Country	△ln(GDP)	△ln(POP)	RE,t-1	constant
EU27	0.141	1.787	-0.705	0.325
Belgium	-0.915	-26.067	-1.057	1.088
Bulgaria	-2.118	-7.263	0.288	-0.026
Czechia	0.577	1.131	-0.505	0.202
Denmark	-0.162	7.699	-0.666	0.207
Germany	0.096	0.439	-1.491	0.723
Estonia	-0.381	-9.200	-0.780	0.111
Ireland	0.104	5.295	-0.939	0.055
Greece	0.371	-1.563	-0.099	0.024
Spain	-0.160	-4.739	-0.666	0.284
France	0.175	-0.189	-0.373	0.140
Croatia	-0.207	-1.777	-0.293	0.122
Italy	-0.100	-2.190	-0.647	0.352
Cyprus	0.360	0.147	-0.538	0.081
Latvia	0.547	12.548	-0.565	0.399
Luthuania	0.182	1.569	-0.545	0.157
Luxembourg	0.108	0.334	-0.428	1.218
Hungary	-1.868	-2.645	0.220	-0.002
Malta	0.005	0.001	-1.110	0.007
Netherlands	0.163	10.124	-1.070	0.665
Austria	-0.075	7.289	-0.563	0.294
Poland	1.961	11.986	-0.237	0.043
Portugal	0.034	-4.200	-0.930	0.286
Romania	-0.349	-10.596	-0.685	0.141
Slovenia	0.073	0.019	-0.506	0.389
Slovakia	-1.295	-5.682	-0.003	0.050
Finland	-1.793	-7.148	-0.396	0.168
Sweden	0.044	-0.549	-0.308	0.121


Belgium
1.20
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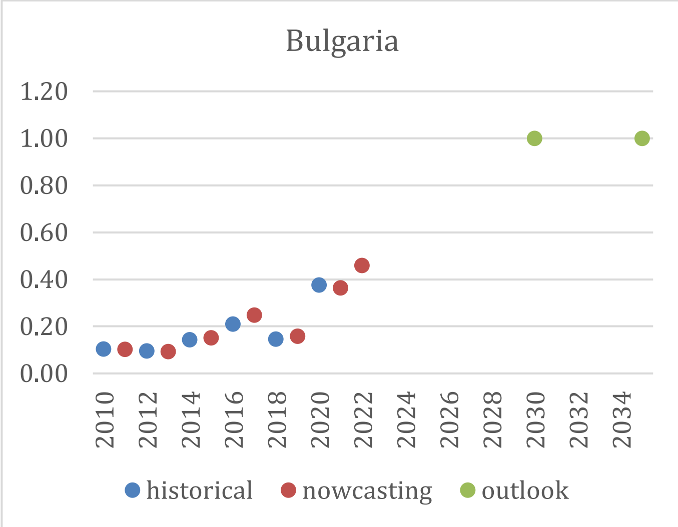
0.60
0.40
0.20
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook


Bulgaria
1.20
1.00
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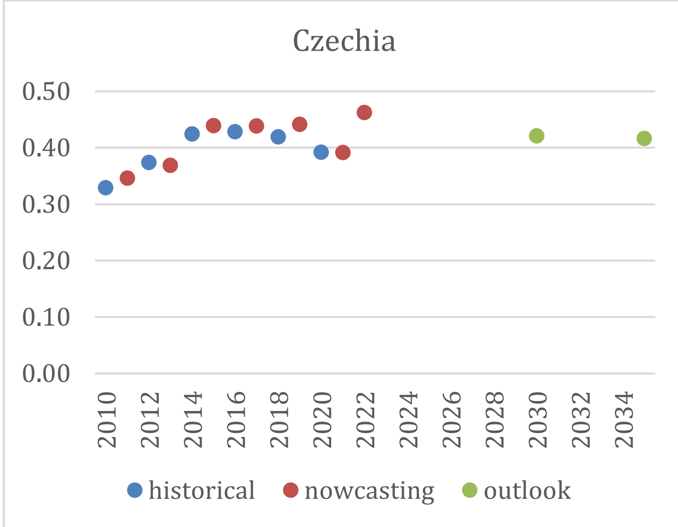
0.60
0.40
0.20
0.00
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030 2032 2034
historical nowcasting outlook


Czechia
0.50
0.40
0.30
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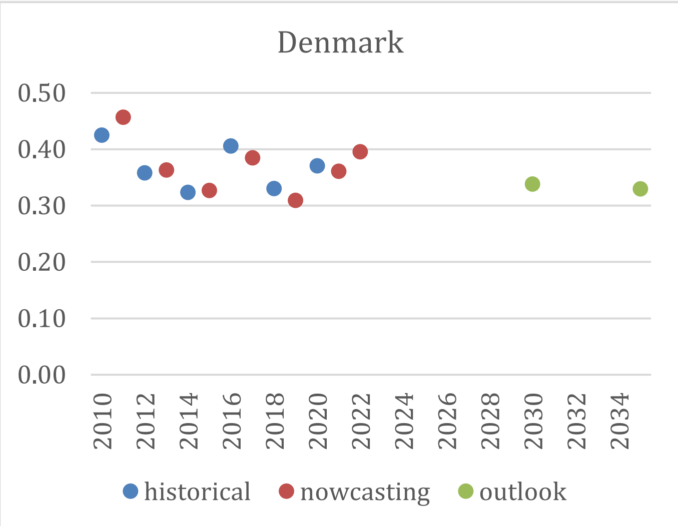
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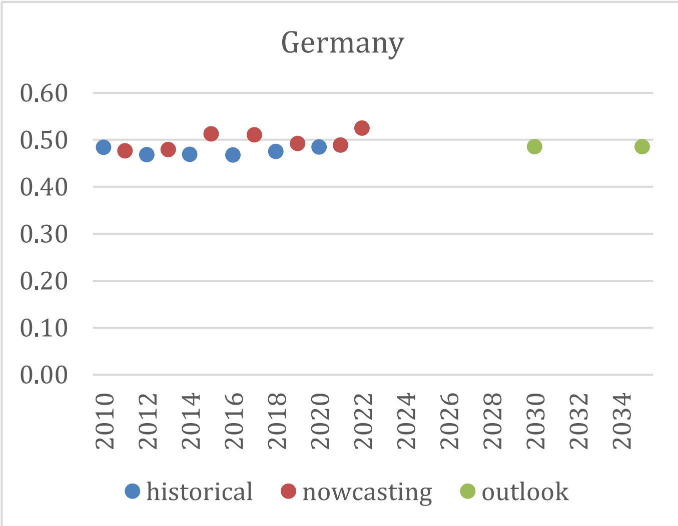
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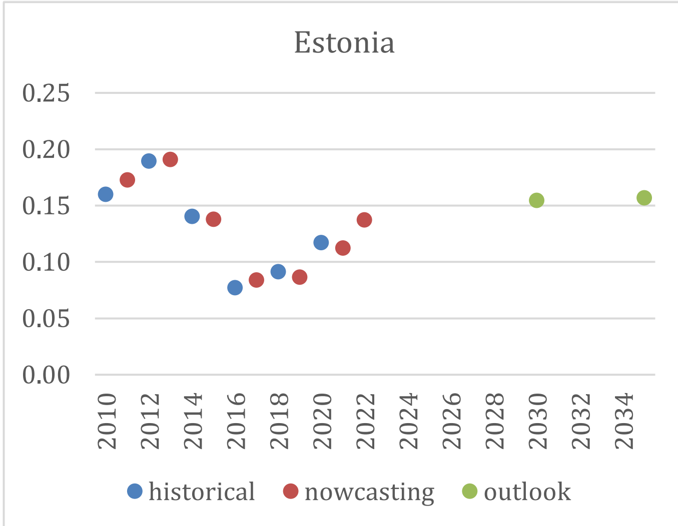
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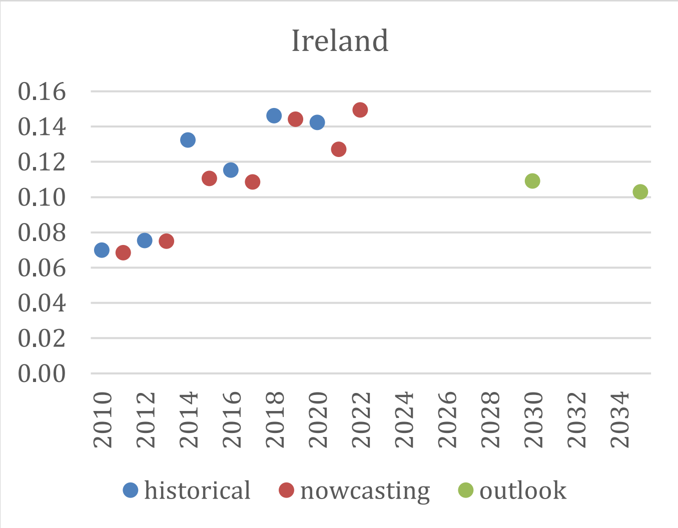
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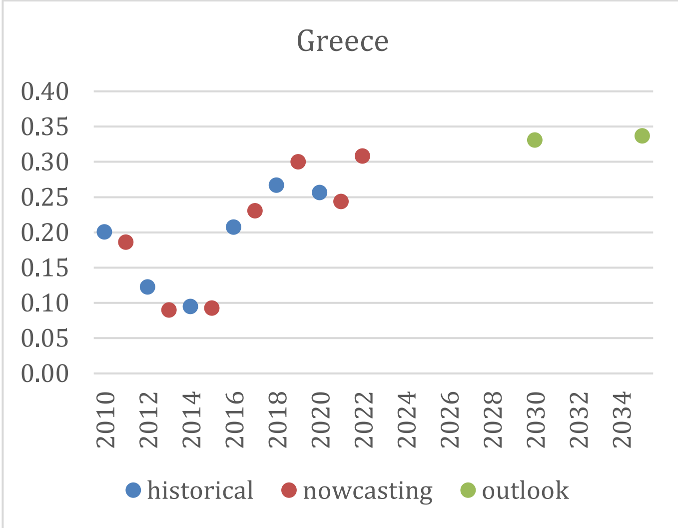
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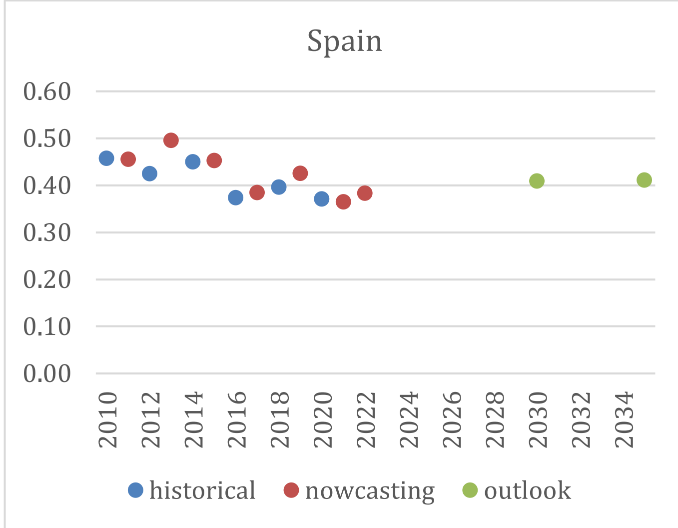
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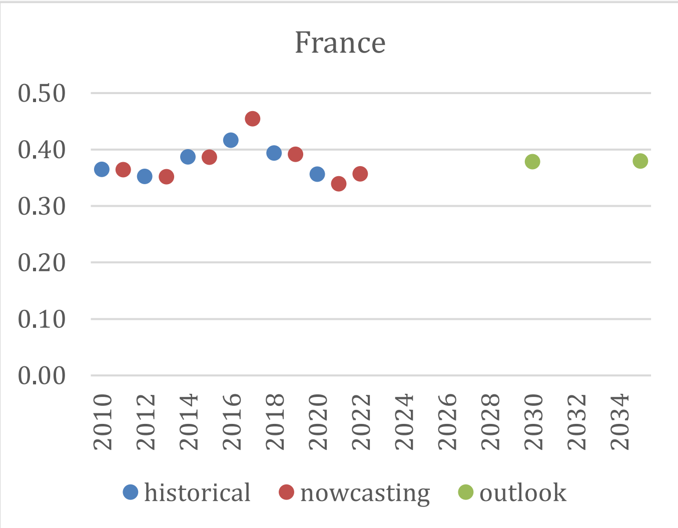
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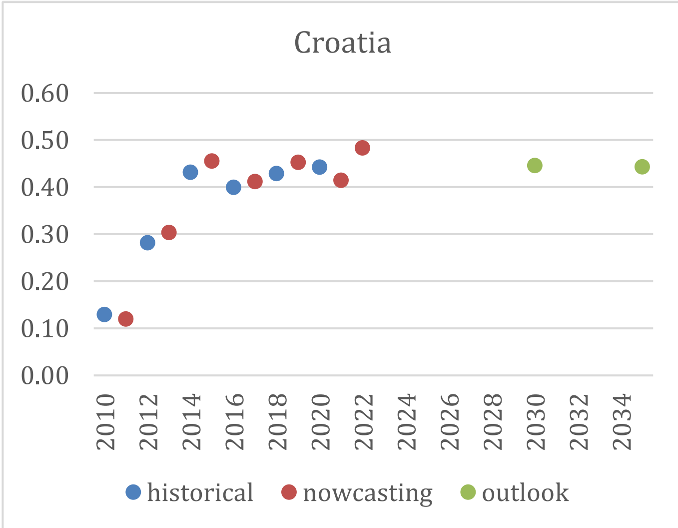
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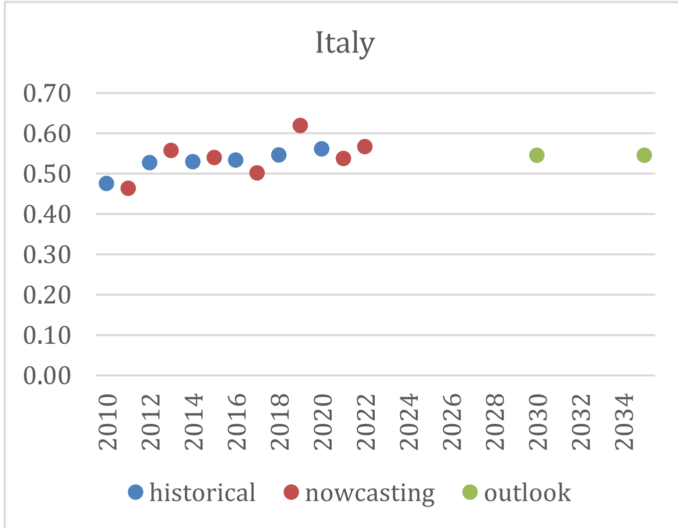
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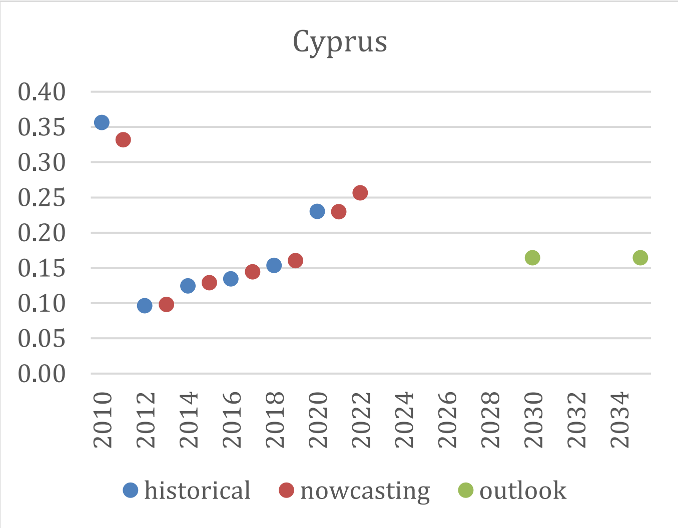
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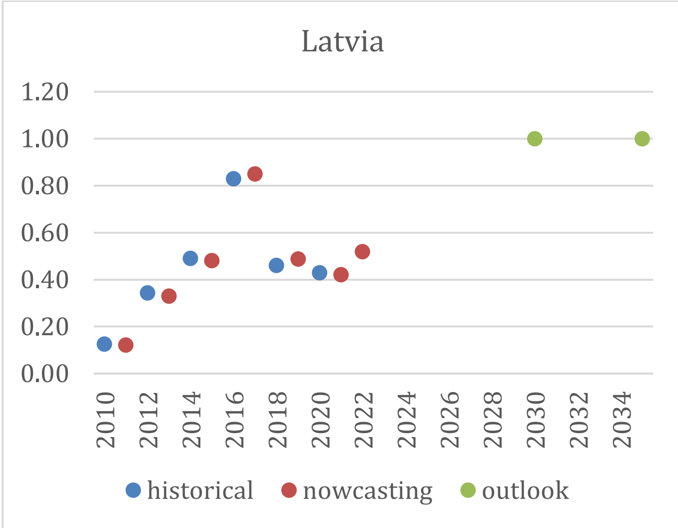
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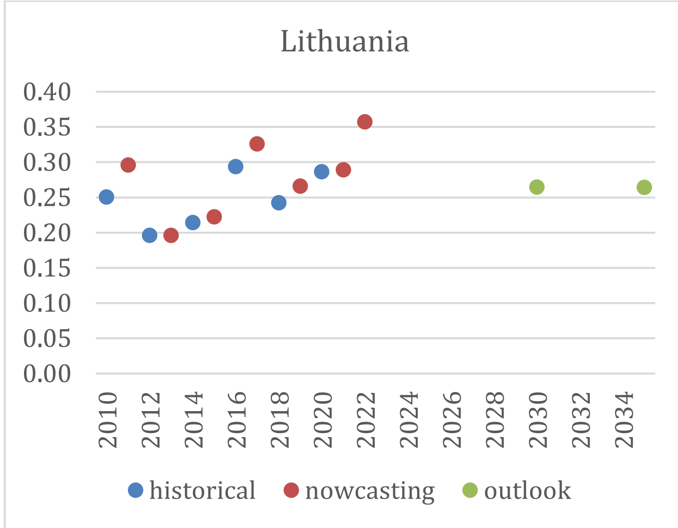
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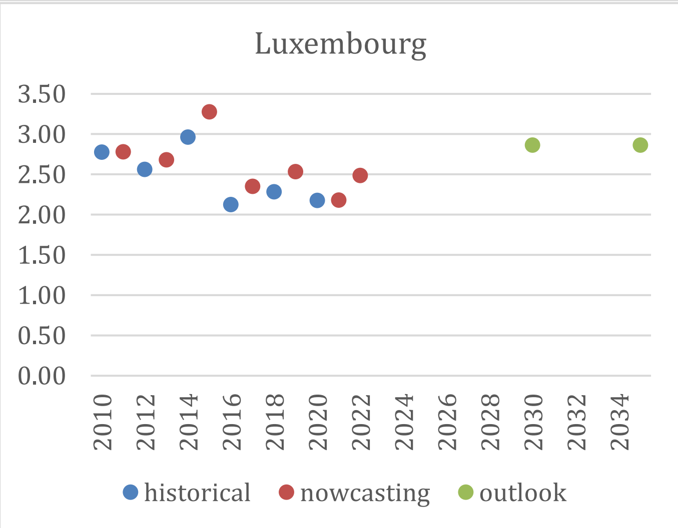
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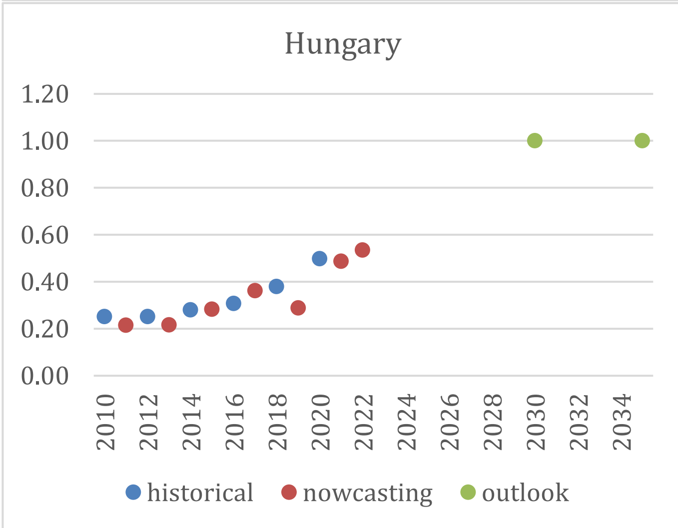
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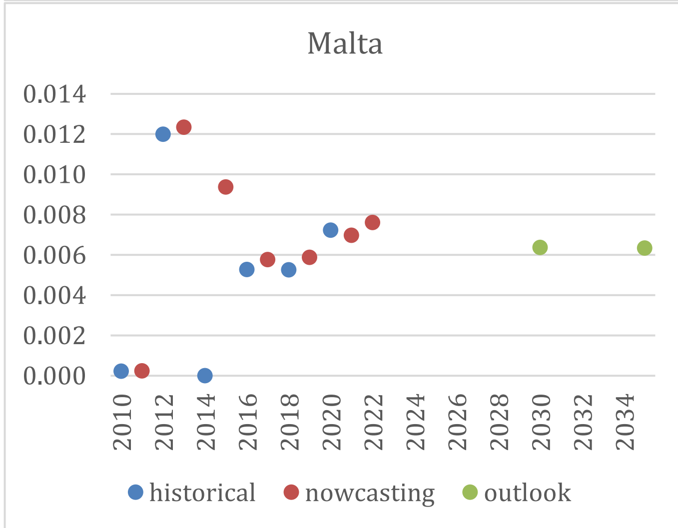
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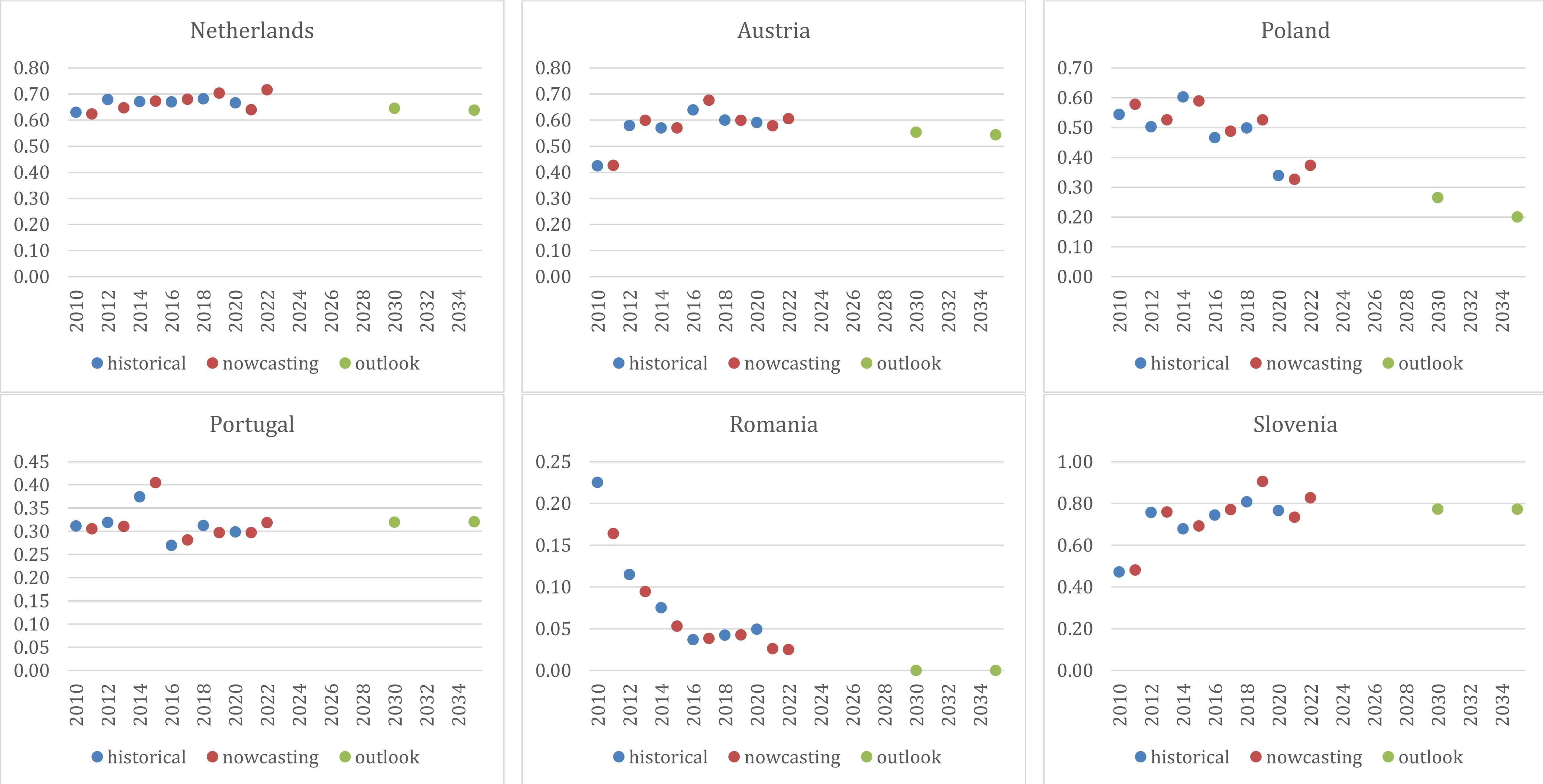
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Poland
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Portugal
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Romania
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Slovenia
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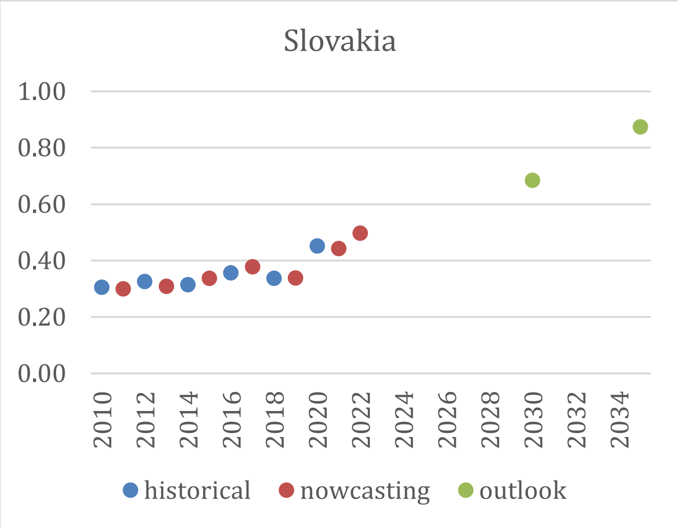

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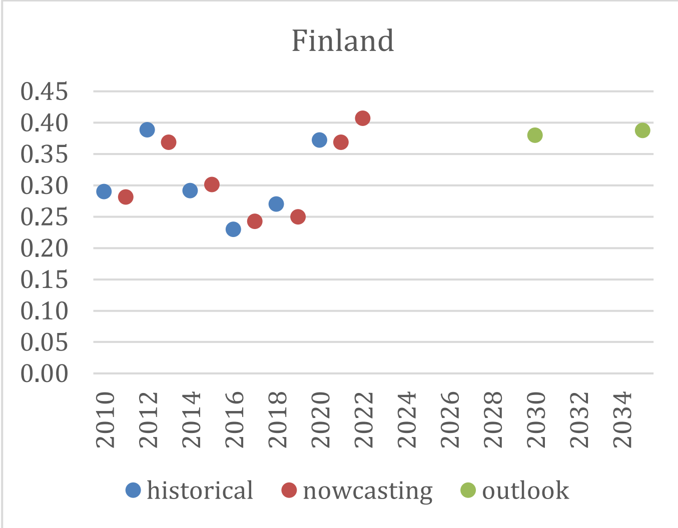

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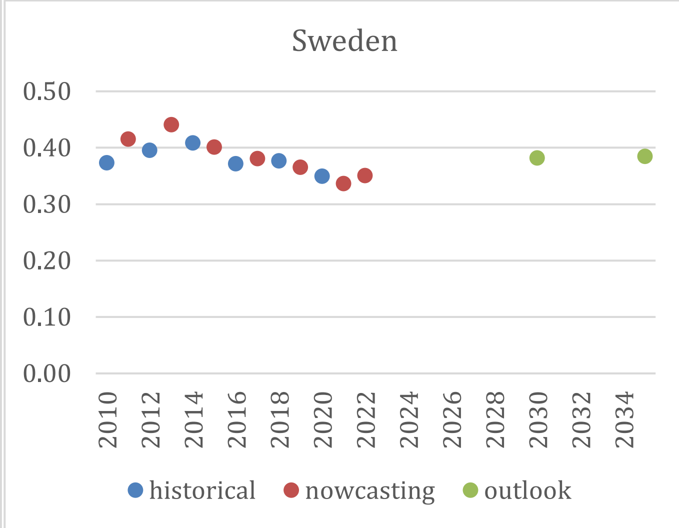

Sweden
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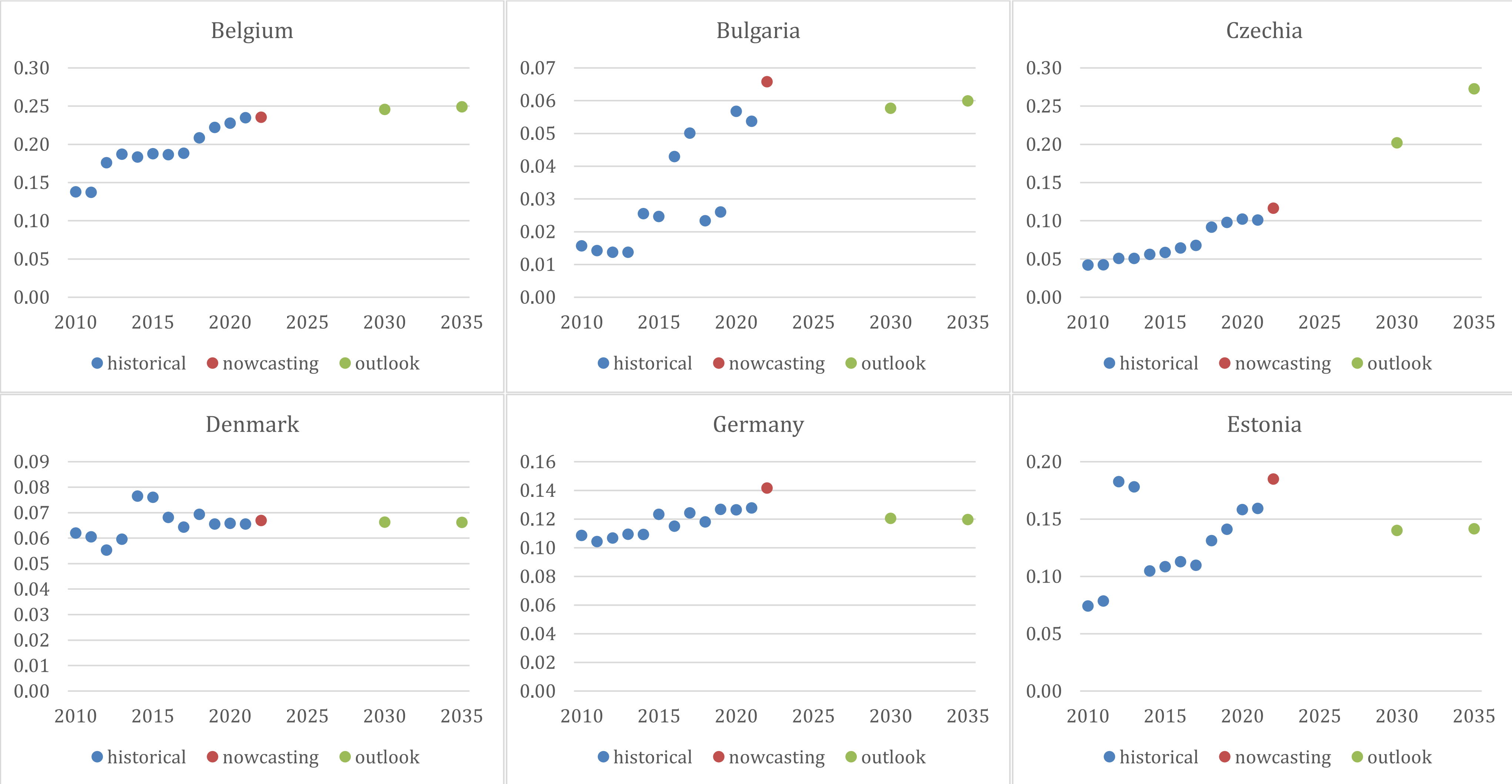
historical
nowcasting
outlook

Circular material use rate (CMUR)

Table A1.6 Results of the econometric exercise

Country	△ln(GDP)	△ln(POP)	CMUR,t-1	constant
EU27	0.030	0.550	-0.479	0.053
Belgium	-0.054	-2.238	-0.297	0.078
Bulgaria	-0.225	1.611	-0.118	0.022
Czechia	0.042	0.491	0.059	0.001
Denmark	0.022	-0.003	-0.561	0.037
Germany	-0.022	0.238	-0.356	0.043
Estonia	-0.432	0.229	-0.778	0.121
Ireland	0.010	0.037	-1.004	0.011
Greece	0.047	0.893	-0.135	0.009
Spain	0.004	1.010	-0.669	0.066
France	-0.008	-0.201	-0.214	0.039
Croatia	-0.009	0.186	-0.140	0.010
Italy	-0.113	-0.675	-0.244	0.048
Cyprus*	-0.007	-0.041	-	0.002
Latvia	0.015	1.656	-0.862	0.051
Luthuania	0.037	-0.002	-0.481	0.013
Luxembourg	-0.107	-1.270	-0.286	0.093
Hungary	-0.019	-3.420	-0.121	-0.002
Malta*	-0.236	0.898	-	0.006
Netherlands	0.102	0.836	-0.616	0.154
Austria	0.005	1.679	-0.198	0.015
Poland	0.323	4.081	-0.312	0.021
Portugal	-0.030	-0.415	-0.393	0.011
Romania	0.002	0.017	-0.373	0.005
Slovenia	0.051	1.260	-0.703	0.068
Slovakia*	-0.505	-6.576	-	0.023
Finland	0.009	0.338	-0.195	0.006
Sweden	-0.132	-0.704	-0.555	0.047
* The inclusion of the lagged level of the indicator led to anomalous results. The variable has been excluded				



Belgium
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historical nowcasting outlook
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Czechia
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Denmark
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Germany
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2010 2015 2020 2025 2030 2035
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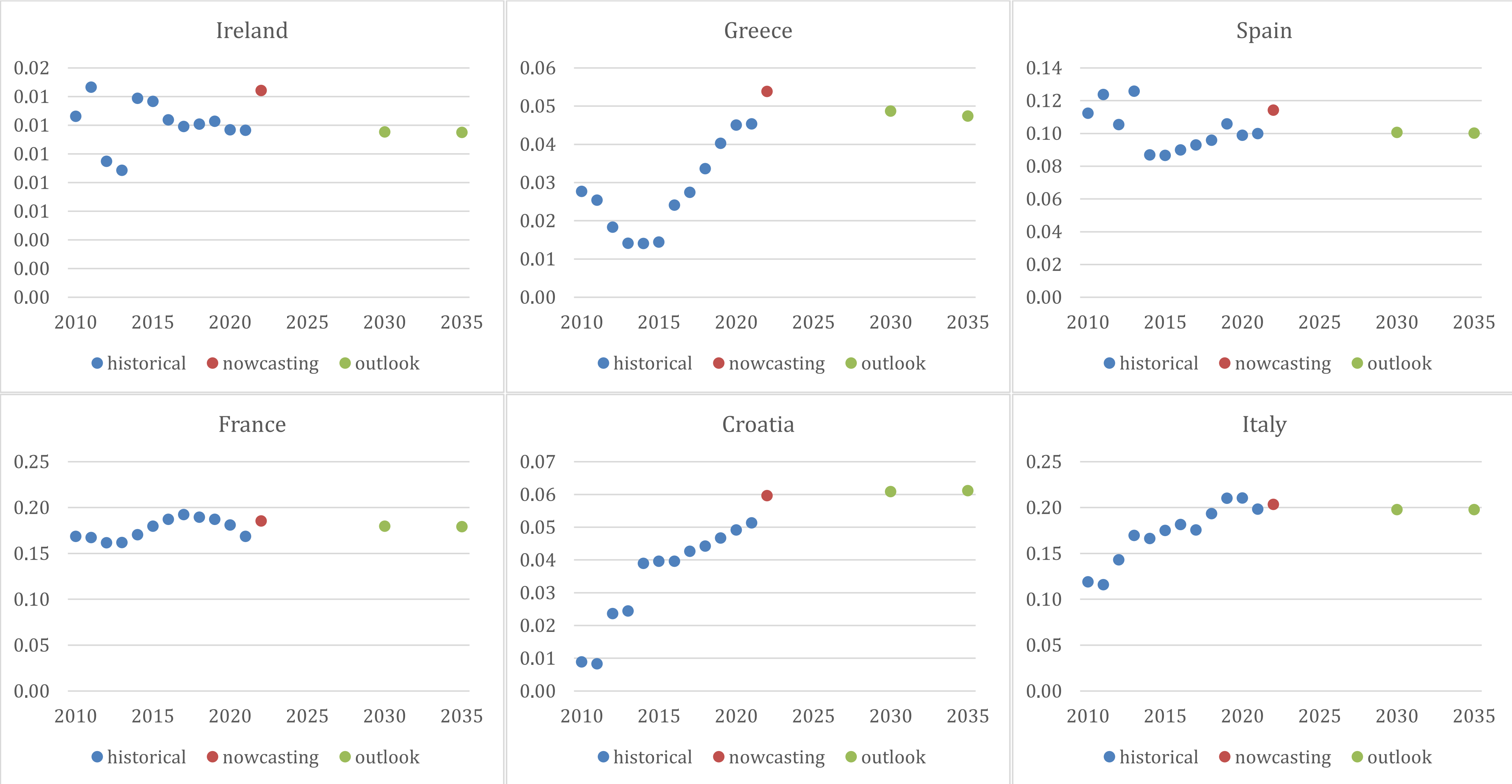
historical nowcasting outlook



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Greece
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Spain
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France
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Croatia
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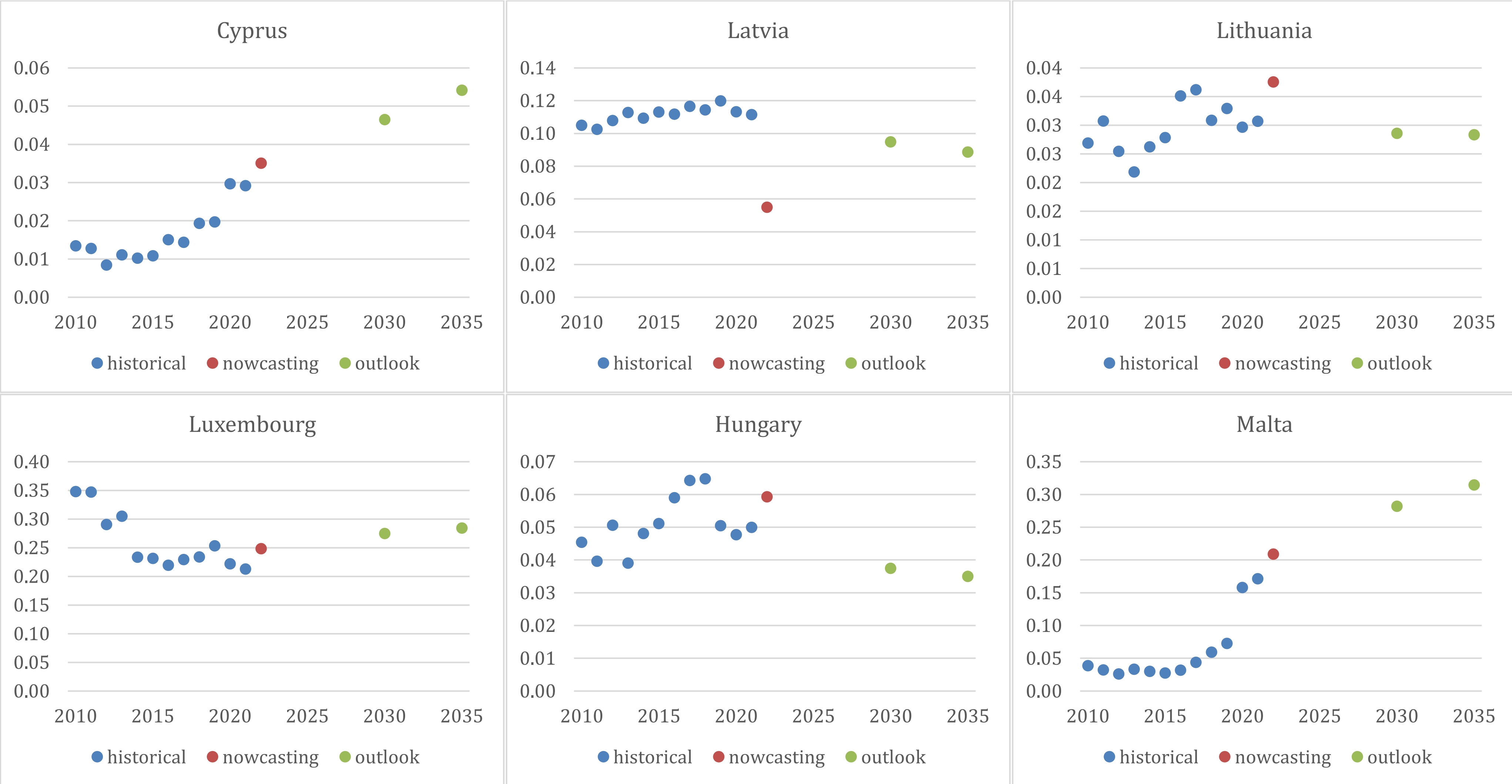
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Hungary
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historical nowcasting outlook
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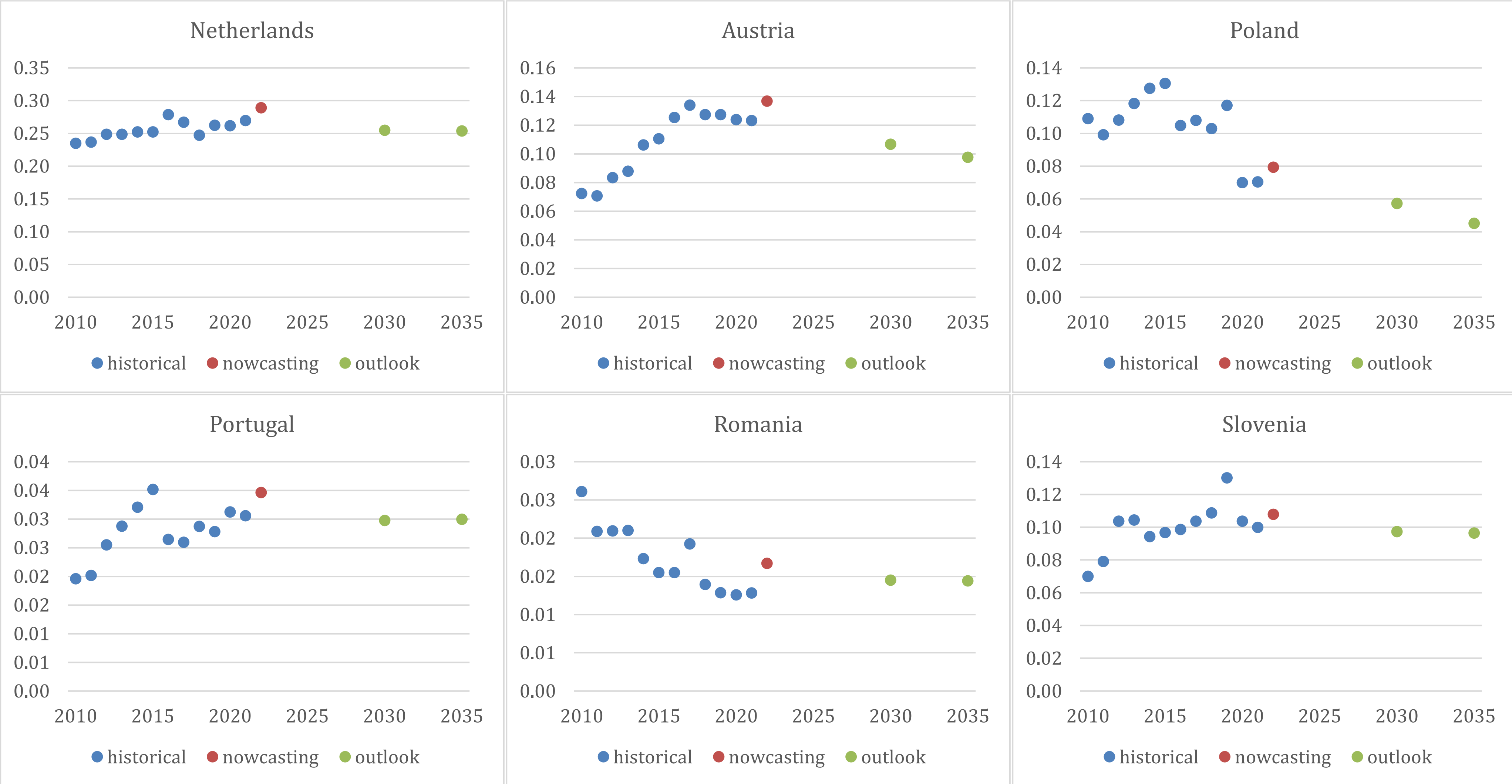
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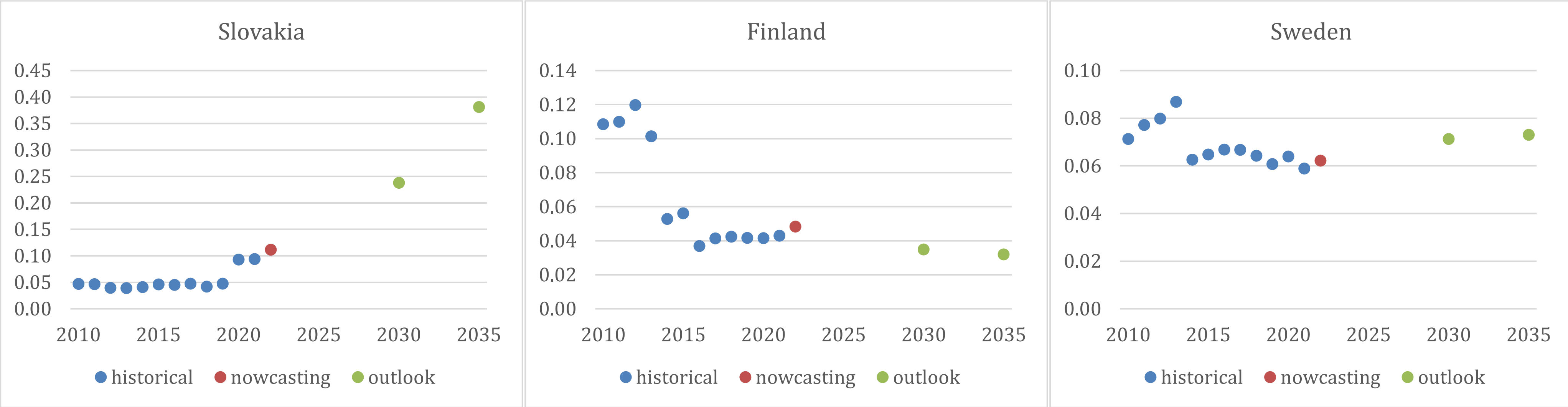

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European Topic Centre on
Circular economy and resource use
https://www.eionet.europa.eu/etcs/etc-ce

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European Environment Agency
European Topic Centre
Circular economy and resource use