EUFORIE
European Futures for Energy Efficiency

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Energy efficiency trends and their drivers
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1. Introduction

Energy efficiency has been a very common and always actual policy objective of the EU and its Member States' energy policies since the 1970s. At a first glance, energy efficiency seems very handy to offer a win-win situation: improving energy efficiency decreases energy use and thus also energy costs, and at the same time, negative impacts related to energy use such as carbon dioxide (CO_2) and other emissions in the air decrease. Thus, improving energy efficiency is considered as an important means to reach the EU climate policy targets as well as other policy goals related to energy use, directly or indirectly.

The European Union has set a target to improve energy efficiency 20% by the year 2020, which means in practice decreasing energy consumption by 20% from the projected energy consumption in the year 2020. To reach the EU target, EU Member States have set their own indicative national energy efficiency targets. Depending on country preferences, the targets can be based on primary or final energy consumption, primary or final energy savings, or energy intensity. The current national projections provided by the Member States, are presented in Table 1.

Energy efficiency is one of the most studied phenomenon in the field of energy and energy policy studies (see, for example, Kasanen 1990; Anderson 1993; Patterson 1996; Sun 1996; Herring 2006; Backlund et al 2012; Proskuryakova & Kovalev 2015). In the Elsevier ScienceDirect service keyword "energy efficiency" can be found in the title of more than 2000 peer-reviewed scientific journal articles.

Energy efficiency, however, is a relative concept, and as such far from being without problems. This is one of the reasons to its popularity both in scientific and political discussions. The win-win solution mentioned above assumes decreasing energy consumption, but actually per unit of production only. The Jevons paradox (see e.g. Polimeni et al 2009) implies that improvements gained by increasing energy efficiency per unit are wasted in additional energy consumption, either by increasing the amount of units, or elsewhere. This kind of argumentation is included also in the Advanced Sustainability (ASA) approach as a "gross rebound effect" (Kaivo-oja et al 2001a; 2001b), which is applied also in this report. Gross rebound effect and the Jevons paradox have quite little to do with energy economists' recent discussion on the rebound effect (cf. Herring 2006) at the micro level, which is, however, based on the same basic idea but focuses to more strict definition. This discussion is, however, beyond the scope of this report.

Energy consumption is a result of three basic drivers as identified widely in many decomposition studies (e.g. Kaivo-oja & Luukkanen 2004): activity effect, intensity effect and structural effect (cf. Kasanen 1990). What is usually meant with energy efficiency, deals directly with only one of these drivers, i.e. the intensity effect. Thus, the intensity effect is essential and on the focus of this first deliverable of the EUFORIE project WP2.

Table 1. Projected energy consumption in the EU Member States in the year 2020. Source: European Commission 2016. Primary/final energy consumption ratio added by the authors.

EU Member State	Energy consumption in 2020 as notified from Member States in 2013, in the NEEAP 2014 or in a separate notification to the European Commission in 2015		
	Primary energy consumption, Mtoe	Final energy consumption, Mtoe	Primary/final energy consumption ratio
Austria	31.5	25.1	1.25
Belgium	43.7	32.5	1.34
Bulgaria	16.9	8.6	1.97
Croatia	11.5	7.0	1.64
Cyprus	2.2	1.8	1.22
Czech Republic	39.6	25.3	1.57
Denmark	17.8	14.8	1.20
Estonia	6.5	2.8	2.32
Finland	35.9	26.7	1.34
France	219.9	131.4	1.67
Germany	276.6	194.3	1.42
Greece	24.7	18.4	1.34
Hungary	24.1	14.4	1.67
Ireland	13.9	11.7	1.19
Italy	158.0	124.0	1.27
Latvia	5.4	4.5	1,20
Lithuania	6.5	4.3	1.51
Luxembourg	4.5	4.2	1.07
Malta	0.7	0.5	1.40
Netherlands	60.7	52.2	1.16
Poland	96.4	71.6	1.35
Portugal	22.5	17.4	1.29
Romania	43.0	30.3	1.42
Slovakia	16.4	9.0	1.82
Slovenia	7.3	5.1	1.43
Spain	119.8	80.1	1.50
Sweden	43.4	30.3	1.43
United Kingdom	177.6	129.2	1.37
Sum of indicative targets EU-28	*1526.9*	*1077.5*	*1.42*
EU-28 target 2020	*1483.0*	*1086.0*	*1.37*

The objective of this report is to provide a comparative analysis on energy efficiency in the EU-28 Member States. The report includes a comparison of the EU Member States at national level, and also a comparison of EU-28 as a whole, the USA and Japan. A comparison of the EU as a whole and China will be provided in EUFORIE WP8. The analyses focus on the national level. Other levels of energy efficiency are dealt with in other Work Packages of the EUFORIE project.

The structure of this report is the following: In this introductory chapter, a general definition of energy efficiency will be provided, and the definition will be applied to the macro level analysis. In the second chapter, the empirical analysis framework based on the Advanced Sustainability (ASA) approach (see Kaivo-oja et al 2001a; 2001b; Vehmas et al 2003; Vehmas 2009) developed in Finland Futures Research Centre (FFRC) will be presented and described. Chapter four presents the indicator-based trends of energy efficiency in the EU-28 Member States. Chapter 4 presents the results from a decomposition analysis of total primary energy supply (TPES), and Chapter 5 the results from a decomposition analysis of carbon dioxide from fuel combustion for EU-28 Member States. Chapter 6 looks at the EU-28 Member States' per4formance related to energy efficiency and provides a ranking without strong conclusions, based on the decomposition results in the previous chapters. Chapter 7 presents the conclusions and policy recommendations from the macro level analysis provided in this first deliverable of the EUFORIE WP2.

In a later stage of the EUFORIE project, the results of this deliverable 2.1 and selected other deliverables provided by the EUFORIE project, will be compared to the results from an analysis of China and reported in D8.5 of WP8 (Chinese energy efficiency and comparison of European/Chinese policy effectiveness).

2. Methodology for analysing changes in energy efficiency at the macro level

2.1. Definition of energy efficiency

In general systems perspective, efficiency refers to a relationship between the input and output of a defined system. Change of efficiency over time brings out the common efficiency idea of getting more from less, which explains the fact that improving energy efficiency has been a common energy policy goal all over the World from the 1970's oil shocks. The idea is that using less energy for a certain task decreases energy consumption and gives better possibilities to use energy sources with a predictable price development, which in practice means domestic energy sources especially in those countries depending on imported crude oil and imported liquid fuels.

When energy use is chosen as an input of a system, energy efficiency refers to a relationship between energy use and the output (Equation 1):

$$Energy\ efficiency = \frac{Output}{Energy\ input} \tag{1}$$

This kind of definition is valid in all systems, and it is not dependent on any scale or type of system *per se*. However, in practice, the system boundary must be clearly defined. In large systems, the energy input usually consists of different energy sources such as electricity, heat, or different types of fuels. Energy efficiency of a system requires that the total energy input to the system is considered. So in large systems, the use of aggregate energy units is relevant. On the other hand, also the output should be considered in total terms, which makes the use of monetary as an alternative if the physical units cannot be easily aggregated. One can argue for focusing on systems with only one energy source and one output product only, but the question how to select the systems for analysis remains. Thus in the EUFORIE project, WP2 focuses on macro level systems at national level. WP6 focuses on company level, and WP3 and WP4 include a set of selected case studies a t different levels in order to bring out the problems related to energy efficiency analysis, and also possible solutions to some problems, at least.

The inverse of the energy efficiency is energy intensity (Equation 2)

$$Energy\ intensity = \frac{Energy\ input}{Output} \tag{2}$$

Energy input in both equations (1) and (2) refers to the energy consumption of the studied system. Change in energy consumption, on the other hand, is not a result of change in energy efficiency or energy intensity alone, it depends also on the activity level of the system, and on the structure of the different activities included in the studied system (Kasanen 1990). Thus, change in energy consumption has an activity effect, an intensity effect, and structural effect.

2.2. Advanced Sustainability Analysis (ASA)

The Advanced Sustainability Analysis (ASA) is an approach based on so-called IPAT identity. The IPAT identity emerged out of the Ehrlich & Holdren/Commoner debate in the early 1970s about the driving forces of global environmental impacts (York et al 2003). The IPAT identity identifies the major drivers of environmental impact (I) at the global level: the amount of population (P), the affluence of that population (A), and level of technology (T). Waggoner and Ausubel (1992) added a new term, consumption (C) in the identity and called the result as an ImPACT identity. Kaya (1990) applied the idea of IPAT identity to identify the drivers of climate change and carbon dioxide emissions. His application has been called as Kaya identity, which has had an influence also to the ASA approach.

Advanced Sustainability Analysis (ASA) is a mathematical information system developed by Finland Futures Research Centre (see e.g. Malaska et al 1999; Kaivo-oja et al 2001a; 2001b; Vehmas et al 2003; Luukkanen et al 2005). The ASA approach can be used to analyze sustainable development from different points of view. The focus is on changes over time between economic and environmental, economic and social, and social and environmental dimensions of sustainability which can be measured with any preferred indicator or index (Fig. 1). The choice of indicators enables the use of ASA approach to specific topics such as energy efficiency in the EUFORIE project. The ASA approach can be applied to all levels of economic activity, from company level to national even to global level.

The ASA approach has been also introduced in the deliverables provided with the previous EU projects DECOIN (Development and Comparison of Sustainability Indicators, FP6, see http://www.decoin.eu) and SMILE (Synergies in Multi-Scale Eco-Social Systems, FP7, see http://www.smile-fp7.eu), so it will not be introduced in detail here but only for those parts applied in the energy efficiency analysis in the EUFORIE project. For the EUFORIE project, instead of a cumulative decomposition with a fixed base year (used in the previous EU projects and in the above mentioned publications), a more precise incremental decomposition based on annual changes and using a moving base year has been carried out.

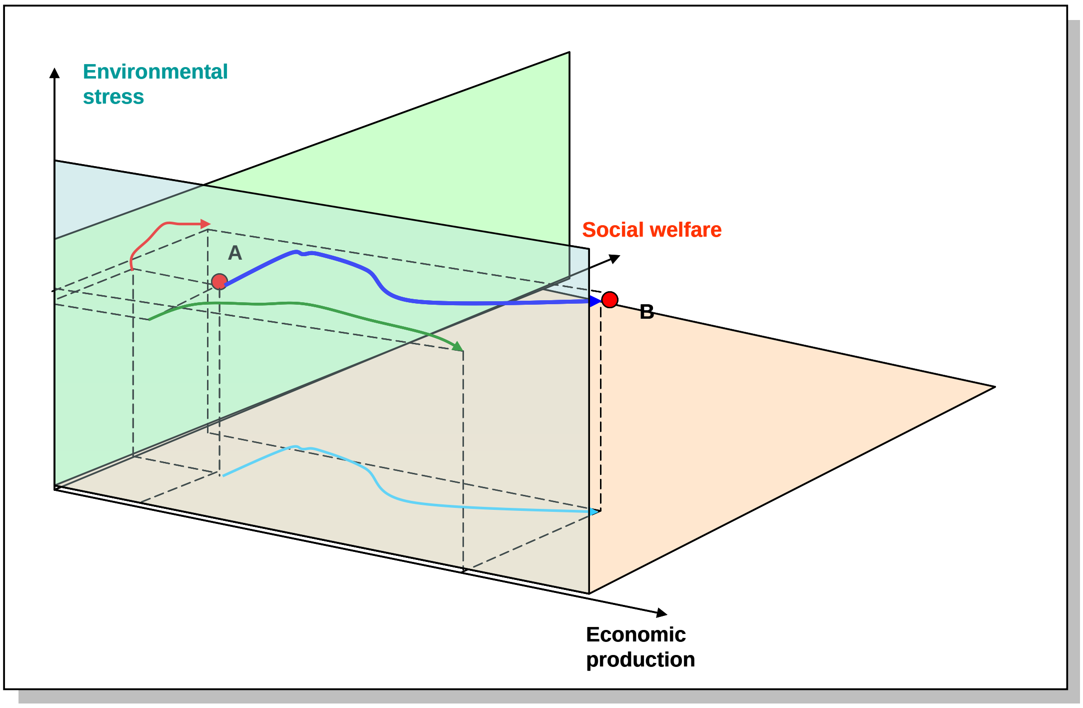

Figure 1. ASA analysis in the different dimensions of sustainability.

The objectives of the ASA approach include the following:

(1) to identify factors contributing to a change in a studied (environmental, social or economic) sustainable development indicator
(2) to estimate the contribution of each factor to the studied change in quantitative terms
(3) define and operationalize new concepts related to sustainable development
(4) to answer policy-relevant what if –type questions related to sustainable development objectives.

The ASA approach is capable of providing tools to fulfil objectives (2), (3) and (4), but objective (1) requires something else such as theoretical or empirical evidence related to the studied phenomena. In the EUFORIE project, especially objective (2) is in the focus, because the ASA approach can be used to analyse the effects of energy efficiency indicators on relevant energy policy goals, such as those related to energy consumption and CO_2 emissions from fuel combustion.

2.3. Basic ASA methodology

ASA applies decomposition analysis in order to divide the observed change in environmental, social or economic indicators into the effects of contributing factors. Identifying the contributing factors in the format required by the ASA approach may be challenging, because selection of potential factors must be supported by theoretical or empirical arguments not based on the ASA approach. The approach itself does not support or give tools for factor identification, so it is based on either theory-based or assumed causal relationship between the identified factors and the studied indicator.

In addition to change in the values of the studied indicator over time, i.e. between two time moments *t-1* and *t* (presented as change in area $\Delta ES_{tt-1} = ES_t - ES_{t-1}$ in Figure 2), the required data consists of values for so-called extensive variables describing change in the size of the studied system (variable X in Figure 2). The extensive variables (X_n , n≥1) can be used to create a series of so-called "intensive" type of variables such as X_{n-1}/X_n, n≥2 (variable ES/X in Figure 2). Typically, these variables may be characterized as "intensities", "efficiencies" or "productivities", depending on the choice of different extensive variables. The sum of the decomposed results (presented as areas in Figure 2), i.e. the contributions of all identified factors, is equal to the total change in the studied environmental, social or economic indicator (area ΔES in Figure 2).

In this basic two-factor decomposition, by choosing energy consumption as variable ES and GDP as variable X, ES/X is energy intensity which also is an inverse of energy efficiency. Variable X shows the Jevons paradox, and it has been called in the ASA approach as a gross rebound effect (to separate from energy economists' rebound effect which is not a macro level concept).

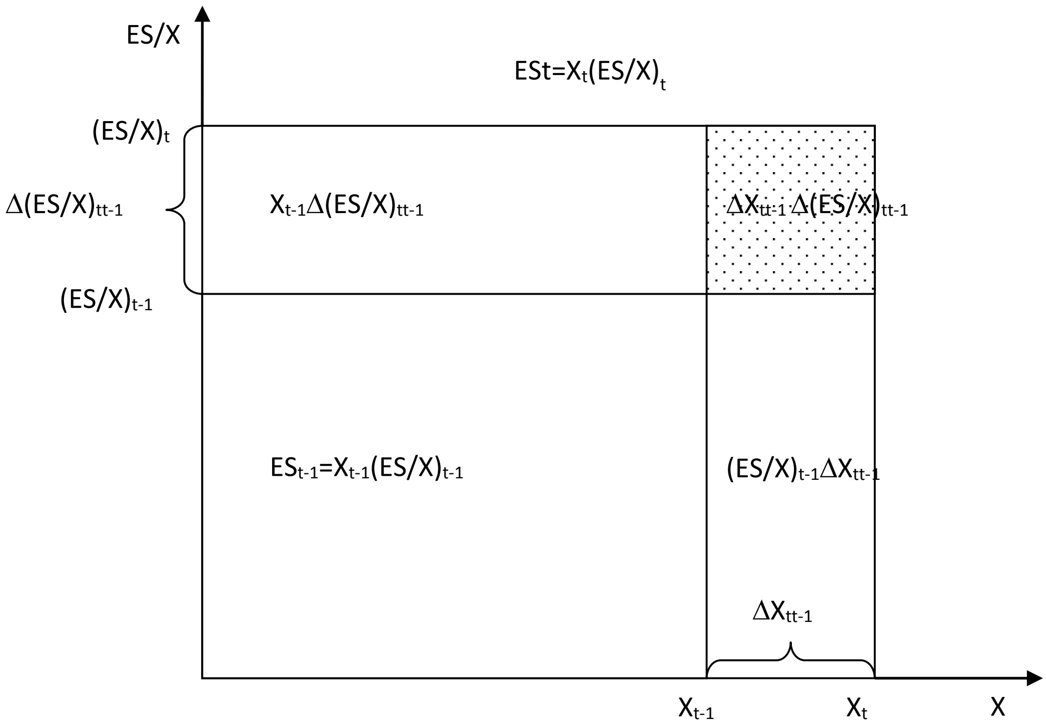

Figure 2. The separate effects of changes in variable X and variable ES/X, and the joint effect of changes in variables X and ES/X to the total change of ES (modified from Sun 1996, 48). The area of the rectangle represents the change in variable ES.

The decomposition analysis calculates the effect/contribution of each explaining factor and their "joint effect" (residual term), which in a complete decomposition must be allocated to the two explaining factors. Figure 2 defines different alternatives for allocating the joint effect: Parameter λ defines the share of the joint effect allocated to the effect of intensive variable ES/X, and 1-λ defines the rest allocated to the effect of extensive variable X.

When λ=0 the joint effect is allocated totally to the effect of variable X, and λ=1 allocates it totally to the effect of variable ES/X. A value of λ=0.5 allocates the joint effect "equally" to both effects (Sun 1998). However, any value between 0 and 1 (0 ≤ λ ≤ 1) can be given to the parameter λ. The allocation can be also made in relation to the relative changes of the contributing effects compared e.g. to their base year values (Equation 3):

$$\lambda = \frac{\left| \dfrac{\Delta\left(\dfrac{ES}{X}\right)_{tt-1}}{\left(\dfrac{ES}{X}\right)_{t-1}} \right|}{\left| \dfrac{\Delta\left(\dfrac{ES}{X}\right)_{tt-1}}{\left(\dfrac{ES}{X}\right)_{t-1}} \right| + \left| \dfrac{\Delta X_{tt-1}}{X_{t-1}} \right|} \tag{3}$$

What is the right value for parameter λ? The choice of the parameter value affects the result, depending on the actual changes in the indicator values selected for investigation (cf. Figure 3). In spite of this, the basic ASA approach with new sustainability-related concepts is based on the choice λ=0. Sun (1996; 1998) has preferred the choice of λ=0.5, which is also selected for the value of all λ parameters used in the decomposition analyses carried out in the EUFORIE project. This choice is in principle the same made in the so-called Sun/Shapley decomposition method, which is considered as one of the preferred methods suggested by Ang (2004).

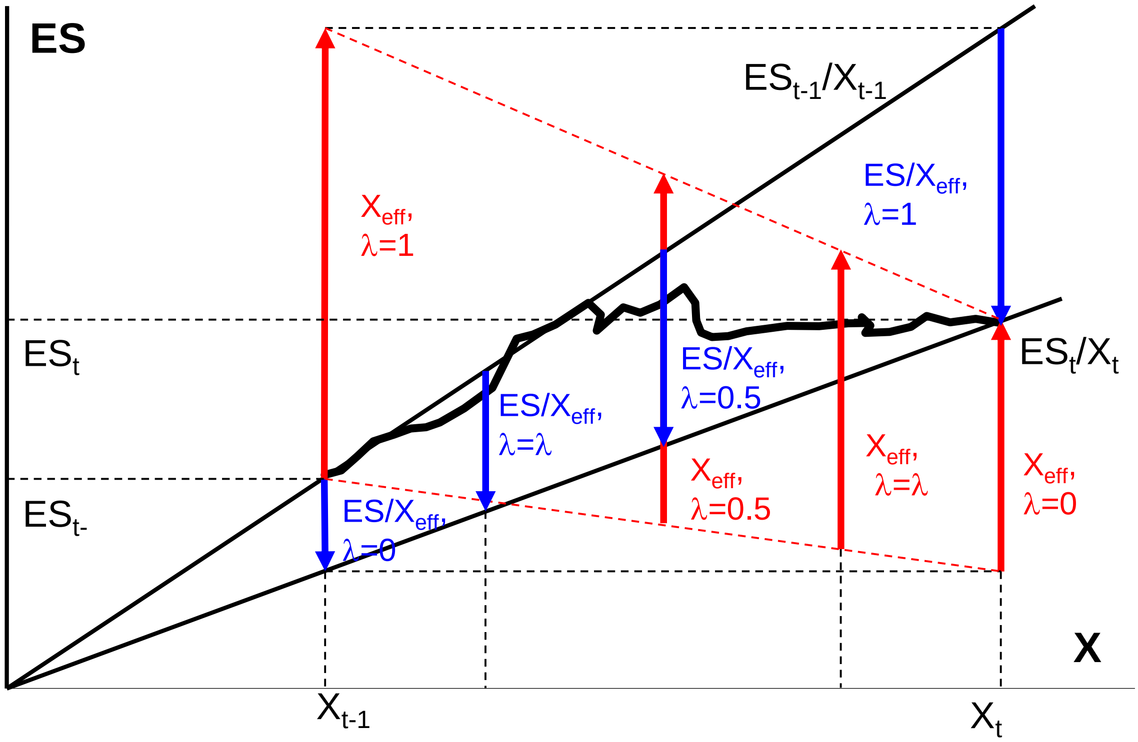

Figure 3. Decomposition of change in variable ES into the contributions of variables X and ES/X by using different values for parameter λ. In the empirical analyses of this report, value λ=0.5 will be used.

In general terms, the contributions of variables V/X and X can be calculated by using the following equations (Equations 4-6b):

$$ES = \frac{ES}{X} \times X \tag{4}$$

$$\Delta ES_{tt-1} = ES_t - ES_{t-1} \tag{5}$$

$$ES / X = \left(X_{t-1} + \lambda \Delta X_{tt-1}\right) \times \Delta\left(\frac{ES}{X}\right)_{tt-1} \tag{6a}$$

$$X = \left[\left(\frac{ES}{X}\right)_{t-1} + (1-\lambda)\Delta\left(\frac{ES}{X}\right)_{tt-1}\right] \times \Delta X_{tt-1} \tag{6b}$$

These equations and Figure 3 clearly show the allocation effect caused by the choice of parameter λ (0 ≤ λ ≤ 1).

2.4. Chained two-factor incremental decomposition

Results of the first two-factor decomposition can be taken as a starting point for further decomposition. This enables taking more factors into account because this "chaining" can be repeated as many times as needed in order to get all the identified factors included in the decomposition equation (“master equation”) taken into account (Equation 7):

$$ES = \frac{ES}{X_1} \times ... \times \frac{X_{n-1}}{X_n} \times X_n \qquad (7)$$

It should be noted that the order of entrance of new factors in the chain when carrying out the decomposition analysis is determined by the theory, or assumptions, behind factor identification. In the following, chained decomposition analysis will be carried out by chaining extensive variables (X_n) in the order presented in the master equations.

In the previous EU projects DECOIN and SMILE, decomposition analysis was carried out for selected relatively long time periods with a fixed base year (“cumulative” decomposition analysis). In the EUFORIE project, decomposition will be made first time for annual changes with a moving base year (“incremental” decomposition analysis). Longer time periods can then be analysed simply by summing up the annual values during the longer time periods. Incremental decomposition makes it easier to choose different time periods when compared to cumulative decomposition analysis.

Decomposition analysis of total primary energy supply (TPES) is based on the following master equation (Equation 8):

$$TPES = \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP \qquad (8)$$

Equation 8 includes five drivers of total primary energy supply (TPES):

- Driver TPES/FEC (total primary energy supply divided by final energy consumption) represents the efficiency of the energy transformation system. This efficiency changes when changes in the transformation process take place, e.g. when fuel use is replaced with electricity. If electricity is produced in condensing power plants, the transformation process becomes more inefficient because in condensing power plants only 35-40 % of the fuel’s energy content is transformed into electricity, the rest is waste heat. Thus, a drop in the efficiency of the energy transformation process increases the need of primary energy (TPES). If CHP is used, the overall efficiency change is smaller, because the heat is not wasted but used for heating purposes either in industrial processes or as district heat (which is common e.g. in Finland).
- Driver FEC/GDP (final energy consumption divided by gross domestic product) describes energy intensity of the economy, which is an inverse of energy efficiency at national level, i.e. GDP productivity of energy use. Changes in this driver are due to changes in the structure of the economy, such as change from energy intensive to lighter industrial branches and services or vice versa.
- Driver GDP/POP (gross domestic product divided by number of population), GDP per capita, describes affluence of the population referred to in the original IPAT identity.

- Driver POP (number of population) was considered as the most important driver in the original IPAT identity which focused on global environmental issues. In energy analysis of industrial countries it is less significant, but defends its position in the driver identification.

The decomposed effects of the factors identified in the master equation of total primary energy supply are calculated as follows in equations 9-11:

$$TPES / FEC = (FEC_{t-1} + \lambda 1_{tt-1} \Delta FEC_{tt-1}) \times \Delta \left(\frac{TPES}{FEC} \right)_{tt-1} \tag{9a}$$

$$FEC = \left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1 - \lambda 1_{tt-1}) \Delta \left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times \Delta FEC_{tt-1} \tag{9b}$$

$$\begin{aligned} FEC / GDP = &\left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1 - \lambda 1_{tt-1}) \Delta \left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times \\ &(GDP_{t-1} + \lambda 2_{tt-1} \Delta GDP_{tt-1}) \times \Delta \left(\frac{FEC}{GDP} \right)_{tt-1} \end{aligned} \tag{10a}$$

$$\begin{aligned} GDP = &\left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1 - \lambda 1_{tt-1}) \Delta \left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times \\ &\left[\left(\frac{FEC}{GDP} \right)_{t-1} + (1 - \lambda 2_{tt-1}) \Delta \left(\frac{FEC}{GDPC} \right)_{tt-1} \right] \times \Delta GDP_{tt-1} \end{aligned} \tag{10b}$$

$$\begin{aligned} GDP / POP = &\left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1 - \lambda 1_{tt-1}) \Delta \left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times \\ &\left[\left(\frac{FEC}{GDP} \right)_{t-1} + (1 - \lambda 2_{tt-1}) \Delta \left(\frac{FEC}{GDP} \right)_{tt-1} \right] \times \\ &\left(POP_{t-1} + \lambda 3_{tt-1} \Delta POP_{tt-1} \right) \times \Delta \left(\frac{GDP}{POP} \right)_{tt-1} \end{aligned} \tag{11a}$$

$$\begin{aligned} POP = &\left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1 - \lambda 1_{tt-1}) \Delta \left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times \\ &\left[\left(\frac{FEC}{GDP} \right)_{t-1} + (1 - \lambda 2)_{tt-1} \Delta \left(\frac{FEC}{GDP} \right)_{tt-1} \right] \times \\ &\left[\left(\frac{GDP}{POP} \right)_{t-1} + (1 - \lambda 3_{tt-1}) \Delta \left(\frac{GDP}{POP} \right)_{tt-1} \right] \times \Delta POP_{tt-1} \end{aligned} \tag{11b}$$

Decomposition of carbon dioxide emissions from fuel combustion (CO2) is based on the following master equation (13):

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP \quad (12)$$

Equation (12) includes five drivers of carbon dioxide from fuel combustion:

- Driver CO2/TPES (carbon dioxide emissions divided by total primary energy supply) represents the carbon intensity of primary energy. The intensity changes due to fuel switch, i.e. change from one primary energy source to another such as from fossil fuels to renewables or from coal to gas etc.
- Driver TPES/FEC (total primary energy supply divided by final energy consumption) represents the efficiency of the energy transformation system. This is the same key driver as in TPES decomposition (Equation 8 above).
- Driver FEC/GDP (final energy consumption divided by gross domestic product) describes energy intensity of the economy, which is an inverse of energy efficiency at national level. This is also the same key driver as in TPES decomposition above.
- Driver GDP/POP (gross domestic product divided by number of population) is the basic indicator of affluence in the original IPAT identity.
- Driver POP (number of population) was originally considered as the most important driver of global environmental impacts. In the chained decomposition approach, it is usually included in the analysis in the final stage of the chaining.

Special reference is made to the key drivers TPES/FEC and FEC/GDP, because they are indicators directly describing energy efficiency at the national level. They may be relevant also at other levels as indicated in other Work Packages of the EUFORIE project.

Ideally, total primary energy supply (TPES) consists of (i) final energy consumption (FEC), (ii) all losses when primary energy is transformed into energy carriers, and (iii) losses in the transfer and distribution of energy carriers (such as electricity) into the sites of final consumption. However, in some cases such as electricity generation from hydro, wind, solar, geothermal, and nuclear energy, measuring the amount of primary energy is difficult or impossible. In these cases different practices have been developed. In International Energy Agency statistics, which are used in the empirical analyses of this report, hydro, wind and solar power are included as electricity in the primary energy, so statistically their transformation is 100% efficient. In the case of nuclear, on the other hand, it has been assumed that electricity is generated with a 33% thermal efficiency. In other words, one unit of nuclear electricity requires three units of primary energy. In the case of geothermal electricity, a 10% thermal efficiency is assumed – one nit of geothermal electricity requires ten units of primary energy. Thus, a comparison between different countries is challenging – e.g. the difference between Norway (with lot of hydro) and France (lot of nuclear) may look too large in terms of primary energy.

The decomposed effects of the factors identified in the master equation are calculated as presented in equations 13-16:

$$CO2/TPES = (TPES_{t-1} + \lambda 1_{tt-1} \Delta TPES_{tt-1}) \times \Delta\left(\frac{CO2}{TPES}\right)_{tt-1} \quad (13a)$$

$$TPES = \left[\left(\frac{CO2}{TPES}\right)_{t-1} + (1-\lambda 1_{tt-1})\Delta\left(\frac{CO2}{TPES}\right)_{tt-1}\right] \times \Delta CO2_{tt-1} \tag{13b}$$

$$\begin{aligned} TPES/FEC = &\left[\left(\frac{CO2}{TPES}\right)_{t-1} + (1-\lambda 1_{tt-1})\Delta\left(\frac{CO2}{TPES}\right)_{tt-1}\right] \times \\ &(FEC_{t-1} + \lambda 2_{tt-1}\Delta FEC_{tt-1}) \times \Delta\left(\frac{TPES}{FEC}\right)_{tt-1} \end{aligned} \tag{14a}$$

$$\begin{aligned} FEC = &\left[\left(\frac{CO2}{TPES}\right)_{t-1} + (1-\lambda 1_{tt-1})\Delta\left(\frac{CO2}{TPES}\right)_{tt-1}\right] \times \\ &\left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda 2_{tt-1})\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right] \times \Delta FEC_{tt-1} \end{aligned} \tag{14b}$$

$$\begin{aligned} FEC/GDP = &\left[\left(\frac{CO2}{TPES}\right)_{t-1} + (1-\lambda 1_{tt-1})\Delta\left(\frac{CO2}{TPES}\right)_{tt-1}\right] \times \\ &\left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda 2_{tt-1})\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right] \times \\ &\left(GDP_{t-1} + \lambda 3_{tt-1}\Delta GDP_{tt-1}\right) \times \Delta\left(\frac{FEC}{GDP}\right)_{tt-1} \end{aligned} \tag{15a}$$

$$\begin{aligned} GDP = &\left[\left(\frac{CO2}{TPES}\right)_{t-1} + (1-\lambda 1_{tt-1})\Delta\left(\frac{CO2}{TPES}\right)_{tt-1}\right] \times \\ &\left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda 2_{tt-1})\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right] \times \\ &\left[\left(\frac{FEC}{GDP}\right)_{t-1} + (1-\lambda 3_{tt-1})\Delta\left(\frac{FEC}{GDP}\right)_{tt-1}\right] \times \Delta GDP_{tt-1} \end{aligned} \tag{15b}$$

$$\begin{aligned} GDP/POP = &\left[\left(\frac{CO2}{TPES}\right)_{t-1} + (1-\lambda 1_{tt-1})\Delta\left(\frac{CO2}{TPES}\right)_{tt-1}\right] \times \\ &\left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda 2_{tt-1})\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right] \times \\ &\left[\left(\frac{FEC}{GDP}\right)_{t-1} + (1-\lambda 3_{tt-1})\Delta\left(\frac{FEC}{GDP}\right)_{tt-1}\right] \times \\ &\left(POP_{tt-1} + \lambda 4_{tt-1}\Delta POP_{tt-1}\right) \times \Delta\left(\frac{GDP}{POP}\right)_{tt-1} \end{aligned} \tag{16a}$$

$$POP = \left[\left(\frac{CO2}{TPES} \right)_{t-1} + (1 - \lambda 1_{tt-1}) \Delta \left(\frac{CO2}{TPES} \right)_{tt-1} \right] \times$$
$$\left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1 - \lambda 2_{tt-1}) \Delta \left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times$$
$$\left[\left(\frac{FEC}{GDP} \right)_{t-1} + (1 - \lambda 3_{tt-1}) \Delta \left(\frac{FEC}{GDP} \right)_{tt-1} \right] \times$$
$$\left[\left(\frac{GDP}{POP} \right)_{tt-1} + (1 - \lambda 4_{tt-1}) \Delta \left(\frac{GDP}{POP} \right)_{tt-1} \right] \times \Delta POP_{tt-1} \quad (16b)$$

In all equations, subscript *tt-1* refers to a change between a calendar year and the next year. Subscript *t-1* refers to the absolute value of the previous year. Coefficients λ1…λ4 define how the joint effect of the two variables are divided into the corresponding factor in each two-factor decomposition. In all decomposition analyses carried out in the EUFORIE project, λ1=λ2=λ3=λ4=0.5.

3. Energy efficiency trends in the EU-28 Member States

In this chapter, the trends of the energy efficiency related indicators TPES/FEC (total primary energy supply divided by final energy consumption) and FEC/GDP (final energy consumption divided by gross domestic product) are described by using the time series data provided by International Energy Agency (IEA 2015). For most Member States, the data during the years 1971-2013 will be used. For Croatia, Estonia, Latvia, Lithuania, and Slovenia, data is available during the time period 1990-2013.

3.1. Trends of TPES/FEC ratio

Figure 4 shows the TPES/FEC trend during the years 1971-2013 for the Mediterranean EU Member States Cyprus, Greece, Italy, Malta, Portugal, and Spain. The trends are rather stabile in all Member States. Italy and Portugal show the most efficient energy transformation systems, where the rate between TPES and FEC is around 1.2-1.3 during the whole time period.

The trend of Malta is exceptional. The efficiency of the energy transformation system in Malta varies a lot but is much more inefficient than in the other Mediterranean Member States during the whole time period. While the TPES/FEC rate in other Mediterranean Member States varies between 1.2 and 1.6, in Malta the variation takes place between 1.6 and 2.8. The reason can be found in changes in the very few large units of either energy production or industrial consumption.

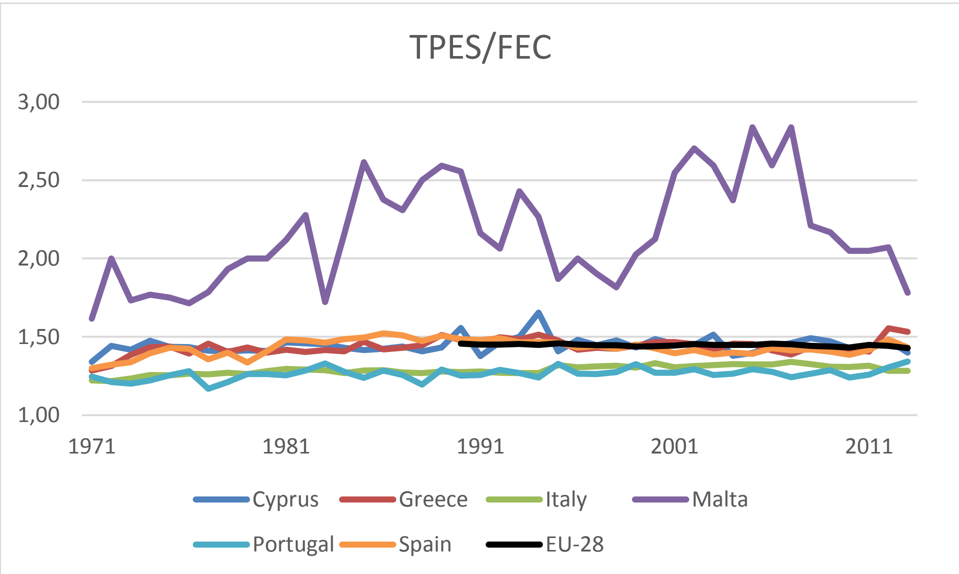

Figure 4. Trend of energy efficiency of the energy transformation system in Cyprus, Greece, Italy, Malta, Portugal and Spain, 1971-2013. Total primary energy supply (TPES in Mtoe) divided by final energy consumption (FEC in Mtoe). The lower the relation value, the better the efficiency.

Figure 5 describes the same trend in the three largest EU Member States, i.e. France, Germany, and the United Kingdom. These Member States differ from each other. France, highly relying on nuclear power, shows an increasing trend of TPES/FEC (from 1.3 to 1.6), which means that the efficiency of the energy transformation system is decreasing. Nuclear electricity is calculated in the IEA statistics as primary energy by dividing the amount of produced electricity by 0.33, and the increasing use of electricity is the major reason for the bad trend of energy transformation efficiency in France. The long period trend of Germany is quite stabile with some annual variation (1.4-1.5), and the trend of the UK is slightly decreasing. This reflects a slight improvement in the efficiency of the energy transformation system over time in the UK.

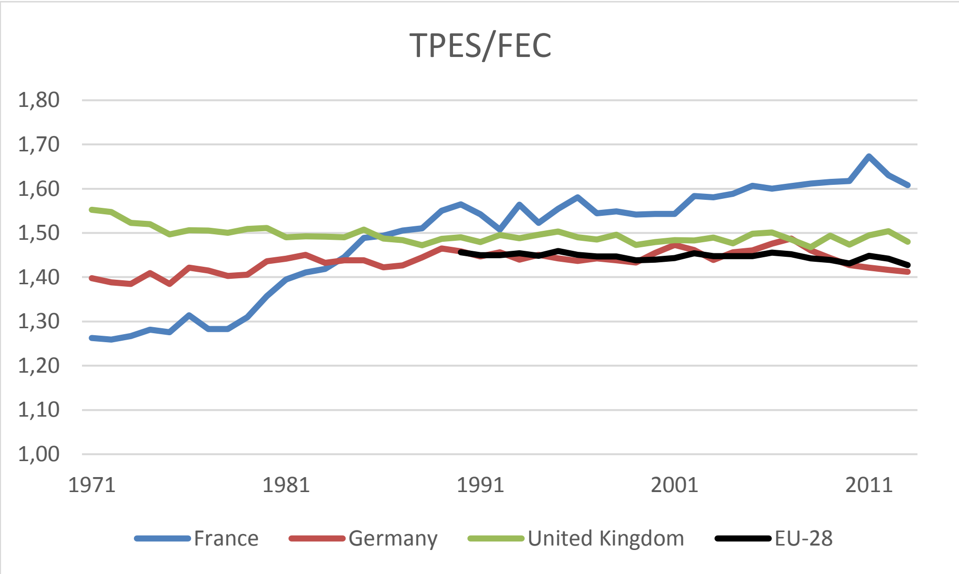

Figure 5. Trend of energy efficiency of the energy transformation system in France, Germany and the United Kingdom, 1971-2013. Total primary energy supply (TPES in Mtoe) divided by final energy consumption (FEC in Mtoe). The lower the relation value, the better the efficiency.

In the Northern EU Member States, Denmark, Finland and Sweden (Figure 6), the TPES/FEC trend varies quite a lot. One obvious reason for this kind of trend is the variation in imported electricity and hydropower availability (due to changes in precipitation). The long-term TPES/FEC trend of Denmark has turned into a decreasing one while the trends of Sweden and Finland are still increasing. A major reason to the increasing trend is, as in all Western economies, is the increasing use of electricity produced with a relatively low efficiency. Thus, the share of electricity in final energy consumption increases, and the value of TPES/FEC increases, i.e the energy transformation system becomes more inefficient.

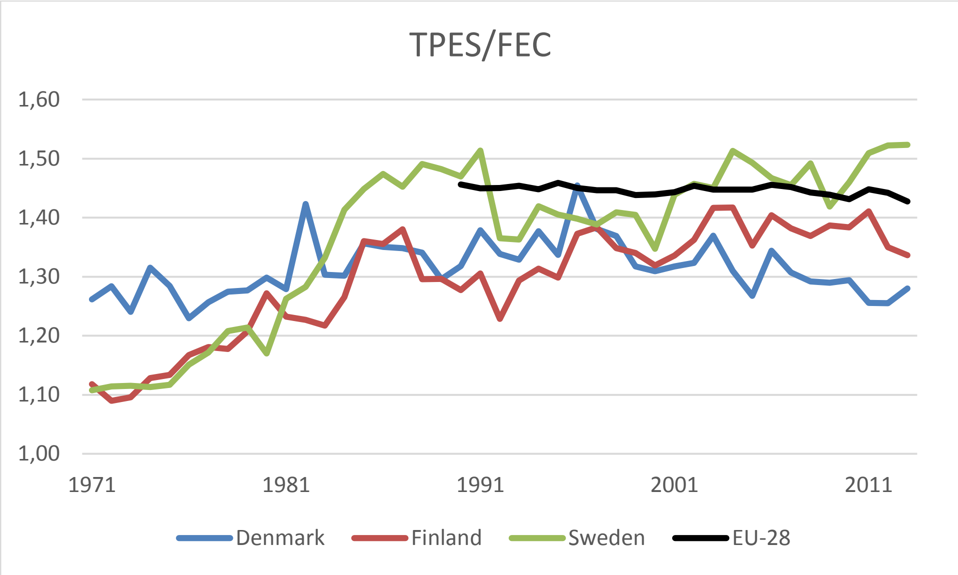

Figure 6. Trend of energy efficiency of the energy transformation system in Denmark, Finland and Sweden, 1971-2013. Total primary energy supply (TPES in Mtoe) divided by final energy consumption (FEC in Mtoe). The lower the relation value, the better the efficiency.

In Figure 7, the trends of TPES/FEC for the Benelux countries Belgium, Luxembourg and the Netherlands, as well as for Austria and Ireland are presented. In general, a slightly decreasing trend can be observed from the 1990s onwards, Luxembourg is an exception because changes in one factory may change the whole system because of the extremely small size of the economy. In the 2000s, the TPES/FEC value of Luxembourg is closest to the minimum value 1.0 among all EU-28 Member States.

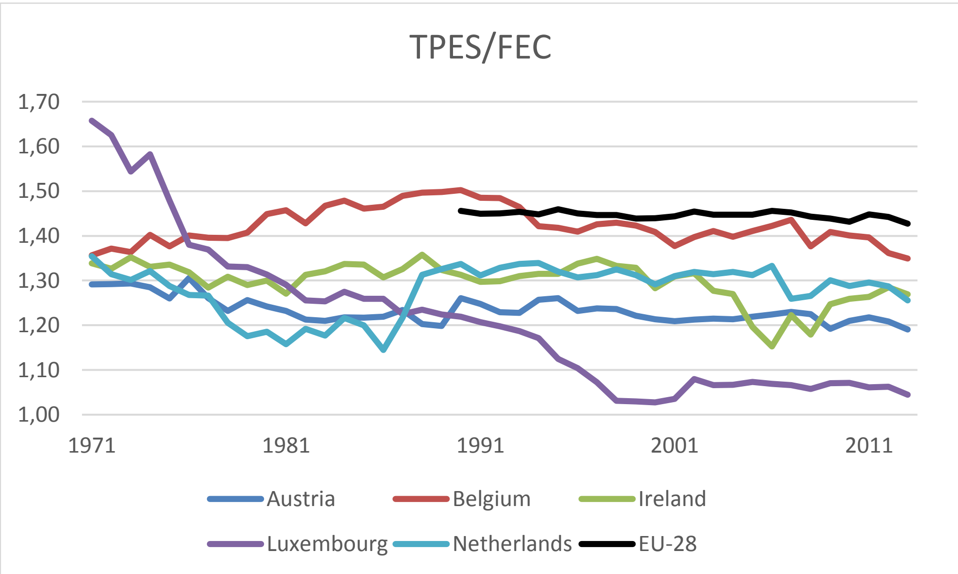

Figure 7. Trend of energy efficiency of the energy transformation system in Austria, Belgium, Ireland, Luxembourg and the Netherlands, 1971-2013. Total primary energy supply (TPES in Mtoe) divided by final energy consumption (FEC in Mtoe). The lower the relation value, the better the efficiency.

The Baltic Member States Estonia, Latvia and Lithuania show very different trends of TPES/FEC (Figure 8). Based on the IEA (2015) data, Latvia has the most efficient energy transformation system of the Baltic countries. The TPES/FEC trend of Estonia and Lithuania varies quite a lot which is a common case in small EU Member States. However, the energy transformation system of Estonia is among the most inefficient ones in the EU.

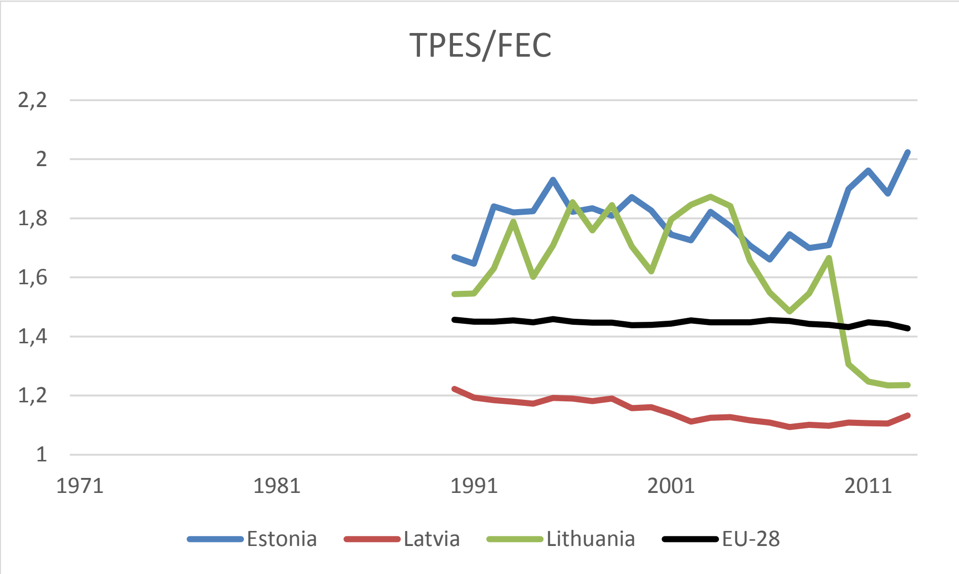

Figure 8. Trend of energy efficiency of the energy transformation system in Estonia, Latvia and Lithuania, 1990-2013. Total primary energy supply (TPES in Mtoe) divided by final energy consumption (FEC in Mtoe). The lower the relation value, the better the efficiency.

The East European EU Member States Czech Republic, Hungary, Poland and Slovakia have performed in two different ways regarding their TPES/FEC trends (Figure 9). When the old Czechoslovakia collapsed, the TPES/FEC trend of Czech Republic started to increase, and the trend of Slovakia decreased rapidly. Shortly after that the trend of Slovakia started to increase again. Hungary and Poland, on the other hand, have had decreasing TPES/FEC trends since the 1990s. As such, the energy transformation systems of all these EU Member States are not among the efficient ones.

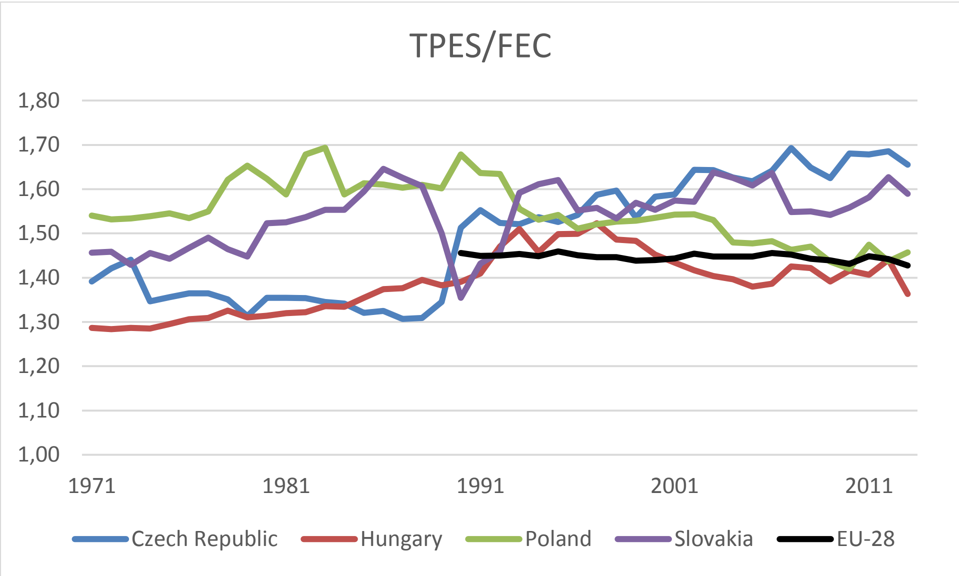

Figure 9. Trend of energy efficiency of the energy transformation system in Czech Republic, Hungary, Poland and Slovakia, 1971-2013. Total primary energy supply (TPES in Mtoe) divided by final energy consumption (FEC in Mtoe). The lower the relation value, the better the efficiency.

Figure 10 shows the TPES/FEC trends of four Member States recently joining the European Union. The trends of Croatia and Slovenia are decreasing during the period of their data availability (1990-2013). During the same period, also the trend of Romania is a decreasing one while Bulgaria still tends to increase its trend. Bulgaria has quite an ineffective energy transformation system in the light of the IEA data.

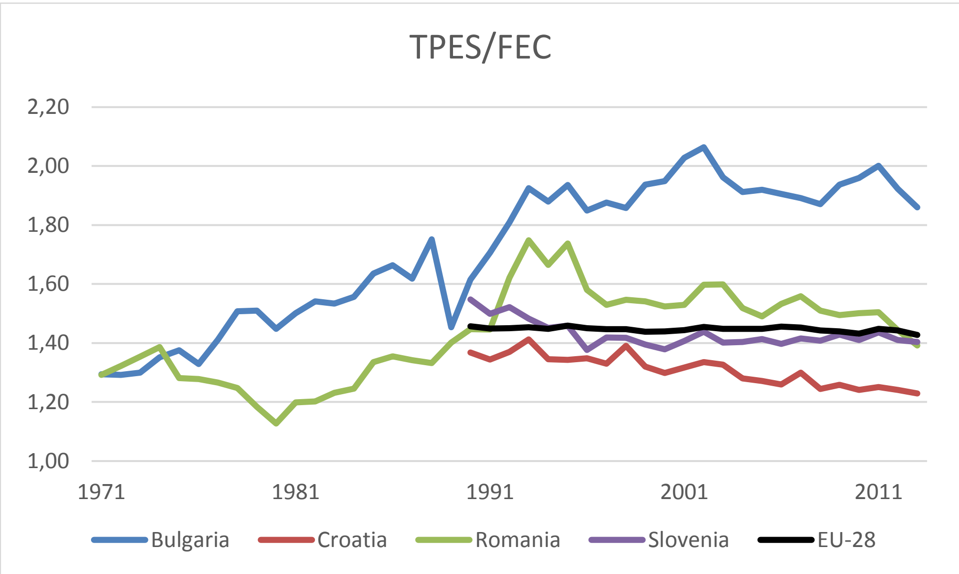

Figure 10. Trend of energy efficiency of the energy transformation system in Bulgaria, Croatia, Romania and Slovenia, 1971/1990-2013. Total primary energy supply (TPES in Mtoe) divided by final energy consumption (FEC in Mtoe). The lower the relation value, the better the efficiency.

3.2. Trends of energy intensity (FEC/GDP)

When the trends of energy intensity, an inverse of energy efficiency, are looked at, there are not so many differences as in the case of the trend of TPES/FEC above. In practice all EU-28 Member States show a decreasing trend of energy intensity (FEC/GDP), the major difference is in the rate and starting time of the decrease. In the following, the energy intensity trends are presented by using the same groups of EU Member States as in presenting the TPES/FEC trends above. In general, energy intensity is a poor indicator of energy efficiency at the macro level because there are so many possible reasons for change, starting from structural change in the economy from energy intensive industrial branches to lighter branches and services and ending in technological improvements in a part of energy consuming activities of the society.

Figure 11 shows how energy intensity has changed in the Mediterranean Member States. In this group the change in energy intensity is the smallest among the EU Member States, and in some Member States such as Greece, Portugal and Spain the decrease has started quite recently. Italy has a nice slightly decreasing trend of energy intensity from the early 1970s, while in the energy intensity trend of small island countries Malta and Cyprus there is quite a lot of variation. Malta was an exception in the case of TPES/FEC trend, and has an increasing trend of energy intensity in the most recent years of the analysis.

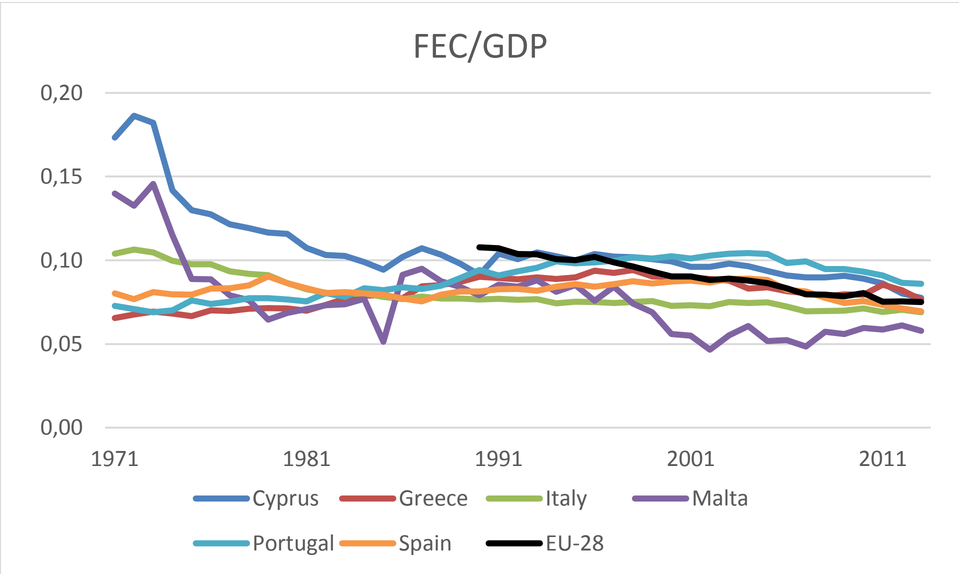

Figure 11. Trend of inverse energy efficiency (energy intensity) of the national economy in Cyprus, Greece, Italy, Malta, Portugal and Spain, 1971-2013. Final energy consumption (FEC) divided by gross domestic product (GDP), Mtoe/1000 USD_{2005}.Data source: IEA 2015.

Figure 12 shows the long-term decreasing trend of energy intensity in the large EU Member States France, Germany and the United Kingdom. The level of energy intensity recently reached by the UK, 0.05 Mtoe/1000 USD_{2005}, is one of the lowest in the whole European Union. Denmark (Figure 13 below) and Ireland (Figure 14 below) are the closest competitors. In these Member States, one Mtoe of consumed energy produces GDP worth 20 000 USD_{2005}.

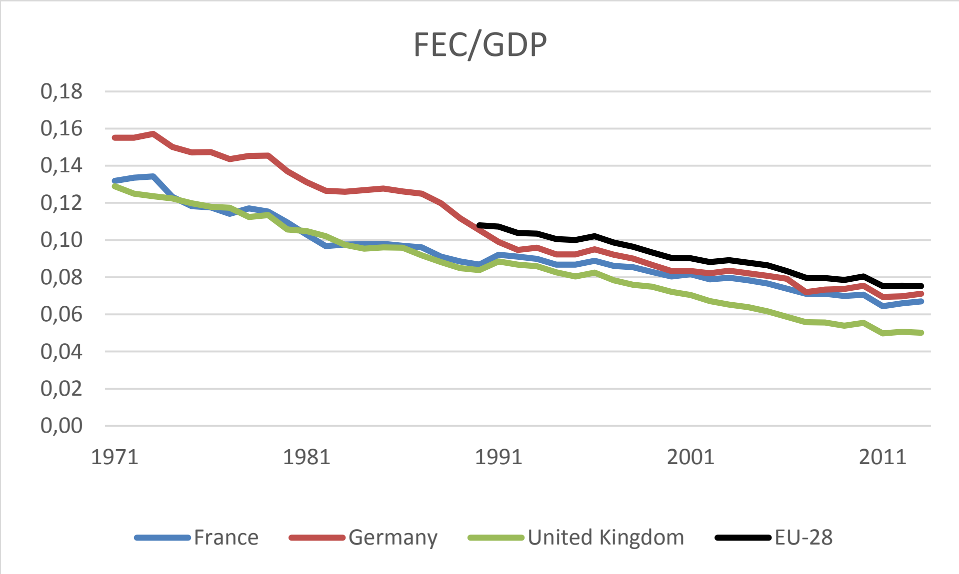

Figure 12. Trend of inverse energy efficiency (energy intensity) of the national economy in France, Germany, and the United KIngdom, 1971-2013. Final energy consumption (FEC) divided by gross domestic product (GDP), Mtoe/1000 USD_{2005}. Data source: IEA 2015.

In the Nordic Member States Denmark, Finland and Sweden (Figure 13), a clear decreasing trend of energy intensity can be observed. Only during the recession periods the decreasing trend has been shortly interrupted in Finland and Sweden. As noted above, Denmark has reached a level of energy intensity among the lowest in the whole EU.

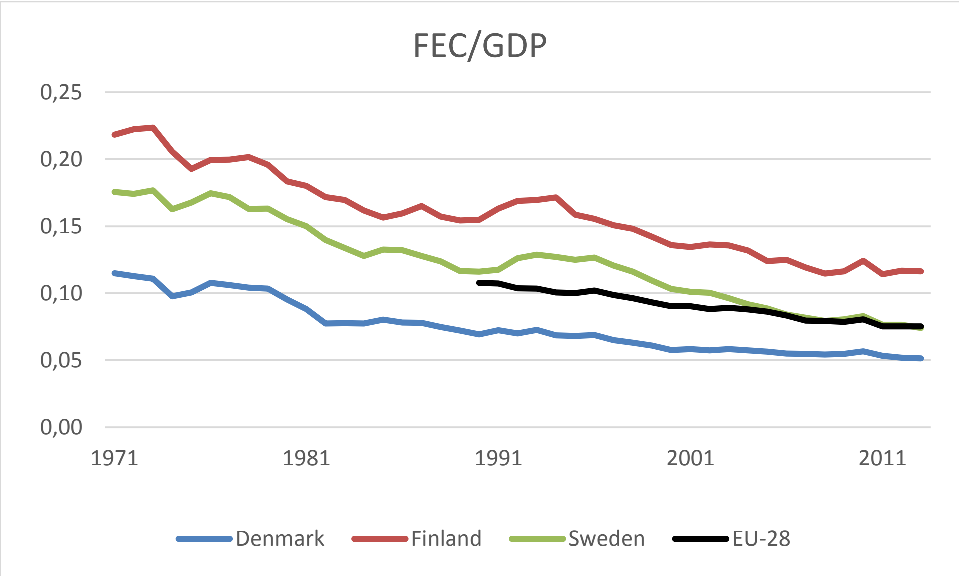

Figure 13. Trend of inverse energy efficiency (energy intensity) of the national economy in Denmark, Finland and Sweden, 1971-2013. Final energy consumption (FEC) divided by gross domestic product (GDP), Mtoe/1000 USD_{2005}. Data source: IEA 2015.

Figure 14 describes the energy intensity trends in the Benelux countries Belgium, Luxembourg and the Netherlands, and also in Austria and Ireland. The trends are decreasing ones, and Ireland together with Denmark (Figure 13 above) and the UK (Figure 12 above) has had one of the lowest energy intensities in the European Union during the recent years. The 2013 values, for example, were 0.047, 0.050 and 0.051 Mtoe/USD_{2005} for Ireland, the UK and Denmark, respectively, while the value for EU-28 was 0.075 Mtoe/USD_{2005} in 2013.

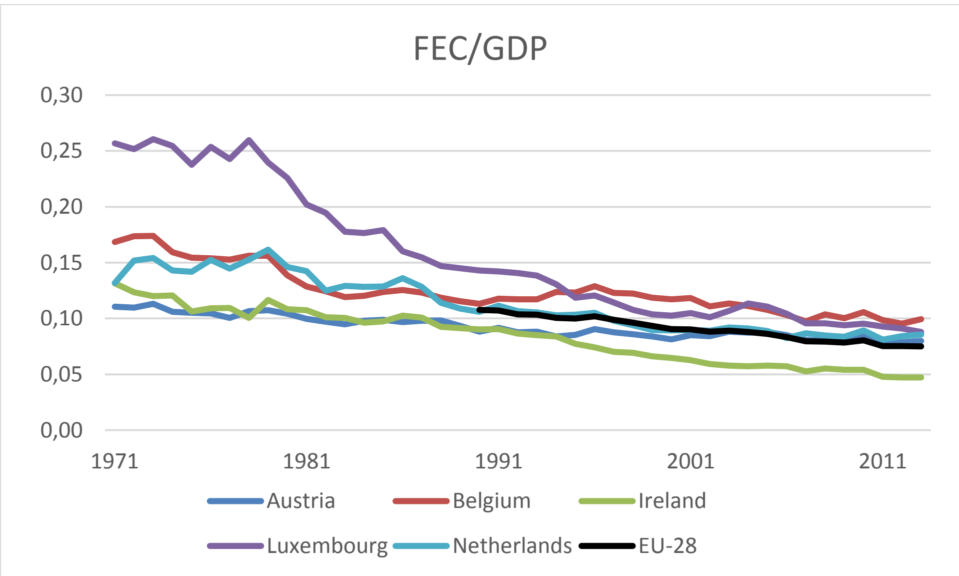

Figure 14. Trend of inverse energy efficiency (energy intensity) of the national economy in Austria, Belgium, Ireland, Luxembourg and the Netherlands, 1971-2013. Final energy consumption (FEC) divided by gross domestic product (GDP), Mtoe/1000 USD_{2005}. Data source: IEA 2015.

The Baltic Member States have data in the IEA database from the year 1990 onwards. In these countries, however, the decrease of energy intensity has been quite a rapid one (Figure 15). However, these Member States still have quite a high energy intensity rate around 0.2 Mtoe/1000 USD_{2005}, which is clearly above the EU-28 average.

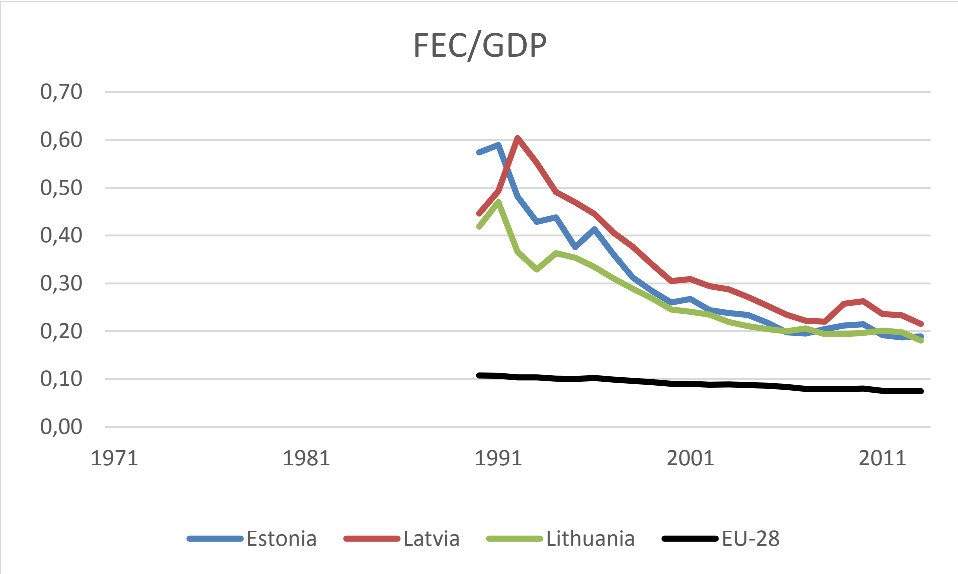

Figure 15. Trend of inverse energy efficiency (energy intensity) of the national economy in Estonia, Latvia and Lithuania, 1990-2013. Final energy consumption (FEC) divided by gross domestic product (GDP), Mtoe/1000 USD_{2005}. Data source: IEA 2015.

The East European Member States Czech Republic, Hungary, Poland, and Slovakia also have a decreasing trend in energy intensity (Figure 16). The trends have turned into continuous decrease in the 1990s, before that there have been several increasing phases too. The most recent values are very close to each other, around 0.15 Mtoe/!000 USD_{2005}.

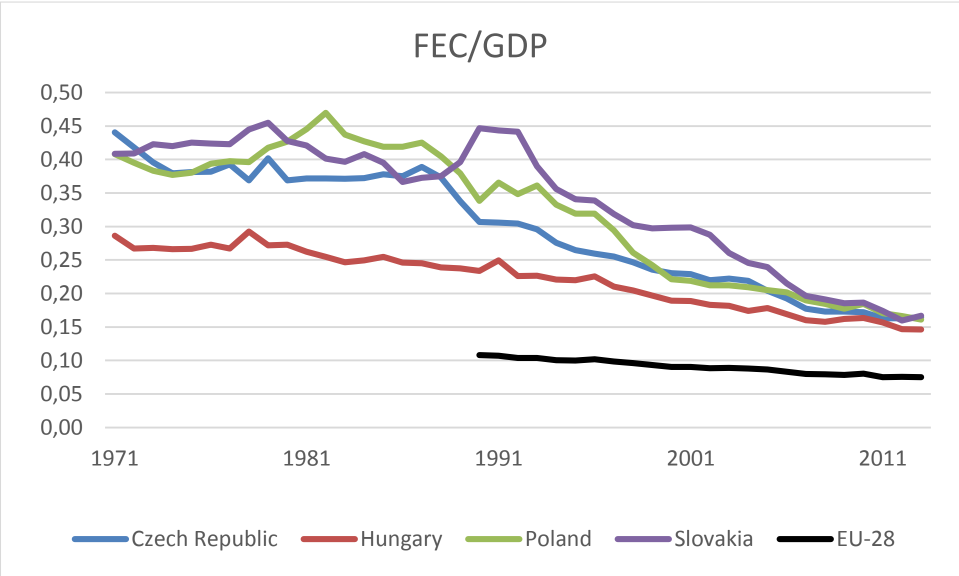

Figure 16. Trend of inverse energy efficiency (energy intensity) of the national economy in Czech Republic, Hungary, Poland and Slovakia, 1971-2013. Final energy consumption (FEC) divided by gross domestic product (GDP), Mtoe/1000 USD_{2005}. Data source: IEA 2015.

Figure 17 shows how the energy intensity trends of Bulgaria and Romania have come down from the high values in early 1970s towards the level of 0.2 Mtoe/1000 USD_{2005}. In comparison, the trends of Croatia and Slovenia are quite flat, but their nicely decreasing trends during the 2000s are hidden by the scale of Figure 17 caused by the high 1970s values of Bulgaria and Romania.

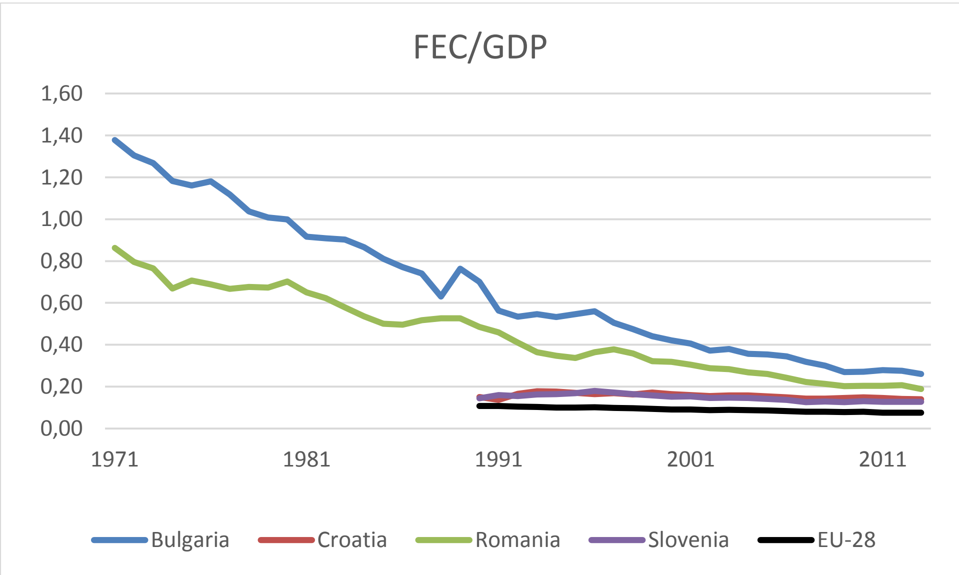

Figure 17. Trend of inverse energy efficiency (energy intensity) of the national economy in Bulgaria, Croatia, Romania and Slovenia, 1971/1990-2013. Final energy consumption (FEC) divided by gross domestic product (GDP), Mtoe/1000 USD_{2005}. Data source: IEA 2015.

4. Decomposition of total primary energy supply (TPES)

After looking at the trends of energy efficiency related indicators TPES/FEC and FEC/GDP, the effects of these indicators to total primary energy supply (Chapter 4) and carbon dioxide emissions from fuel combustion (Chapter 5) are analysed. The reason for this kind of analysis is that in addition to keeping increasing energy efficiency as a policy target *per se*, energy efficiency – as energy in general – can be considered as a means to more concrete policy targets such as reducing energy use and decreasing CO_2 and other emissions directly caused by energy use.

One of the major policy targets of improving energy efficiency is to reduce energy use without a need to limit the activities where energy is used in the society. Nowadays energy efficiency is taken as a policy target as such, but from the era of oil crises in the 1970s "energy saving" was commonly used instead up to the 1990s (cf. Kasanen 1990). Energy efficiency can be improved in the energy consumption side (final energy consumption) and in the energy production side (transforming primary energy into energy carriers). It is worth noting here, that the EU energy efficiency target is not related to energy efficiency per se, but energy consumption in relation to projected future consumption.

The decomposition analysis gives an insight to what extent these policy targets have been reached, and also an insight to the role of the Jevons paradox (cf. Polimeni et al 2009). In the following, change total primary energy supply (ΔTPES) will be decomposed into the relative contributions of the drivers described above in Equation 8. Data used in this decomposition activity is taken from the International Energy Agency online database (IEA 2015). This data includes total primary energy supply (TPES), final energy consumption (FEC), gross domestic product (GDP) in real prices (in 2005 USD, adjusted by exchange rates), and number of population. The data used in the analyses covers the years 1990-2013 and it is the most recent data available from International Energy Agency (IEA 2015).

The results are based on an analysis of incremental (annual) changes, and they are always presented as percentage of a selected base year value of the decomposed indicator, i.e. total primary energy supply (TPES). Tables 2-5 show results from analyses carried out for the years 1990-2013, divided into four time periods: 1990-2000 (Table 2), 2000-2005 (Table 3), 2005-2010 (Table 4) and 2010-2013 (Table 5). The main results are the relative contributions of the energy efficiency related drivers TPES/FEC and FEC/GDP as well as other drivers defined in Equation 8 above, i.e. GDP/POP and POP, to the change of total primary energy supply (ΔTPES). The incremental effects are summed up for each time period and presented as percentage from the absolute TPES value of the first year of each time period.

In Tables 2-5, for the effects of energy efficiency related drivers (TPES/FEC and FEC/GDP), basic statistical info (median, average, standard deviation and minimum and maximum values) on the annual effects during each of the selected time periods (as percentage of the previous year's TPES value) are presented as well. Appendix 1 incudes charts describing the results of all incremental decompositions of ΔTPES (and ΔCO2, see Chapter 5) for each EU-28 Member State and for EU-15 and EU-28 aggregates during the time period 1990-2013.

Table 2. Results of total primary energy supply (ΔTPES) decomposition analysis for EU Member States and EU15 and EU-28 aggregates, 1990-2000. Cumulative effects are sums of incremental (annual) effects.

EU-28 Member State	ΔTPES 1990-2000, % of 1990 TPES	Cumulative TPES/FEC effect, % of 1990 TPES	Statistical info on incremental TPES/FEC effects, % of previous year's TPES					Cumulative FEC/GDP effect, % of 1990 TPES	Statistical info on incremental FEC/GDP effects, % of previous year's TPES					Cumulative GDP/POP effect, % of 1990 TPES	Cumulative POP effect, % of 1990 TPES
			Md	Av.	Stdev	Min	Max		Md	Av.	Stdev	Min	Max		
Austria	6.6	-1.9	-0.4	-0.4	1.3	-2.3	2.3	-4.1	-2.1	-0.8	3.7	-5.0	6.1	10.6	2.0
Belgium	9.7	-3.1	-0.5	-0.7	1.1	-3.1	1.1	1.2	-0.4	0.4	3.3	-4.7	5.6	10.2	1.4
Bulgaria	-12.9	5.4	2.2	1.8	3.6	-4.6	6.4	-15.2	-5.0	-4.7	6.7	-19.5	2.6	-1.2	-1.9
Croatia	-6.0	-2.0	-0.8	-0.5	3.1	-5.2	4.6	2.6	-2.2	1.0	7.8	-8.3	18.3	-3.5	-3.0
Cyprus	19.8	-1.4	2.3	-0.2	8.2	-15.2	10.5	2.4	-1.3	0.9	5.0	-3.5	13.2	10.4	8.4
Czech	-5.8	1.3	0.8	0.5	2.2	-3.7	3.1	-7.9	-2.6	-2.8	2.0	-6.9	-0.3	1.1	-0.3
Denmark	2.5	-0.3	-0.8	0.1	4.4	-5.0	9.0	-7.4	-3.1	-1.8	3.8	-5.8	4.8	8.7	1.5
Estonia	-14.1	1.9	-0.4	0.7	4.4	-6.1	9.7	-12.9	-9.9	-7.3	9.1	-17.3	9.9	-0.7	-2.4
Finland	7.3	1.6	0.1	0.4	3.6	-5.9	5.8	-8.0	-1.8	-1.3	3.9	-7.7	5.4	11.7	2.1
France	8.1	-1.0	-0.2	-0.1	2.1	-2.6	3.7	-5.6	-1.2	-0.7	3.0	-3.4	6.1	11.5	3.1
Germany	-1.6	-0.1	-0.3	0.0	0.8	-1.2	1.5	-8.5	-3.4	-2.3	2.8	-6.1	3.0	5.8	1.3
Greece	8.1	-0.2	0.2	-0.1	2.2	-4.2	2.5	-0.2	-0.5	0.0	2.3	-4.1	4.4	6.6	1.8
Hungary	-5.8	1.8	0.7	0.4	2.5	-3.4	4.0	-8.1	-2.7	-2.1	4.5	-9.4	6.3	1.2	-0.6
Ireland	12.9	-1.2	0.0	-0.2	1.5	-3.6	1.8	-12.4	-3.1	-3.4	2.6	-8.4	0.1	23.5	3.1
Italy	6.4	1.8	0.1	0.5	1.6	-1.1	4.2	-2.0	0.2	-0.5	1.8	-4.0	1.4	6.5	0.2
Latvia	-21.4	-1.7	-0.5	-0.5	1.3	-2.7	1.6	-5.2	-8.0	-3.8	10.0	-11.1	18.9	-11.3	-3.2
Lithuania	-27.7	2.9	2.3	0.6	7.0	-10.4	8.5	-16.0	-6.9	-4.7	9.3	-20.3	12.0	-13.2	-1.5
Luxembourg	-0.4	-5.2	-1.2	-1.7	1.4	-3.9	-0.1	-10.2	-2.8	-3.3	3.2	-9.1	1.7	10.5	4.6
Malta	-0.4	-5.7	-4.5	-1.5	11.8	-18.5	18.6	-11.0	-4.5	-3.2	10.2	-20.1	11.2	13.7	2.6
Netherlands	5.2	-1.7	-0.4	-0.4	1.2	-2.0	1.3	-8.5	-1.7	-1.7	3.6	-6.9	5.1	12.3	3.1
Poland	-4.2	-2.6	0.0	-0.9	1.9	-5.0	0.7	-11.9	-6.0	-4.2	6.2	-11.6	7.7	10.1	0.2
Portugal	20.6	0.5	0.0	0.2	3.7	-4.8	7.2	4.5	1.1	0.9	2.1	-3.4	4.0	14.0	1.7
Romania	-15.5	1.7	-0.2	0.5	6.0	-9.6	11.0	-11.3	-4.8	-4.0	6.3	-11.5	8.1	-4.8	-1.0
Slovakia	-6.5	4.7	0.9	1.3	3.6	-4.4	8.7	-13.2	-2.9	-4.0	4.3	-12.4	0.3	1.3	0.6
Slovenia	5.2	-5.0	-1.4	-1.2	2.6	-5.9	3.1	1.4	-1.1	0.6	5.2	-4.9	9.7	8.9	-0.2
Spain	15.7	-2.1	-0.3	-0.4	1.3	-2.1	2.0	3.4	1.5	0.7	1.8	-2.0	3.0	12.7	1.7
Sweden	0.7	-8.0	-0.4	-0.8	4.0	-10.1	4.2	-11.7	-1.6	-1.2	4.1	-5.9	6.8	17.1	3.3
UK	3.1	-0.3	0.0	-0.1	0.8	-1.5	1.1	-6.1	-2.3	-1.5	3.2	-5.0	5.4	8.4	1.1
EU-15	*4.3*	*-0.5*	*-0.1*	*-0.1*	*0.4*	*-0.5*	*0.6*	*-5.3*	*-1.6*	*-1.2*	*1.7*	*-3.0*	*1.8*	*8.7*	*1.5*
EU-28	*1.2*	*-0.5*	*-0.1*	*-0.1*	*0.4*	*-0.6*	*0.8*	*-7.3*	*-2.6*	*-1.8*	*1.8*	*-3.3*	*2.0*	*8.1*	*0.8*

Table 3. Results of total primary energy supply (ΔTPES) decomposition analysis for EU-28 Member States, 2000-2005. Cumulative effects are sums of incremental (annual) effects.

EU-28 Member State	ΔTPES 2000-2005, % of 2000 TPES	Cumulative TPES/FEC effect, % of 2000 TPES	Statistical info on incremental TPES/FEC effects, % of previous year's TPES					Cumulative FEC/GDP effect, % of 2000 TPES	Statistical info on incremental FEC/GDP effects, % of previous year's TPES					Cumulative GDP/POP effect, % of 2000 TPES	Cumulative POP effect, % of 2000 TPES
			Md	Av.	Stdev	Min	Max		Md	Av.	Stdev	Min	Max		
Austria	8.5	0.3	0.2	0.1	0.4	-0.4	0.5	3.8	0.7	1.6	2.9	-1.0	4.8	3.0	1.4
Belgium	0.2	0.0	0.9	0.0	1.6	-2.3	1.4	-4.3	-2.1	-1.7	3.4	-6.4	2.2	3.3	1.1
Bulgaria	3.1	-0.7	0.4	-0.3	3.6	-5.1	4.1	-7.8	-3.7	-3.4	4.3	-8.5	2.3	14.0	-2.5
Croatia	6.6	-1.2	-0.7	-0.4	2.1	-3.6	1.5	-3.2	-2.7	-1.3	2.2	-3.0	2.0	10.9	0.1
Cyprus	1.3	-2.2	-0.6	-1.1	5.0	-8.9	4.7	-2.1	-1.5	-1.2	2.3	-3.2	2.1	3.6	1.9
Czech	3.3	0.7	0.0	0.4	1.8	-1.0	3.5	-4.4	-1.5	-2.4	3.1	-6.9	1.1	7.1	-0.1
Denmark	0.5	-1.3	0.4	-0.6	3.2	-4.3	3.5	-0.8	-1.5	-0.4	2.0	-2.0	1.9	2.0	0.6
Estonia	3.4	-2.3	-2.8	-1.3	4.1	-4.6	5.7	-6.2	-2.6	-3.5	4.7	-9.0	3.0	13.0	-1.0
Finland	3.7	1.5	1.3	0.6	3.2	-4.5	4.0	-6.1	-1.1	-1.8	2.7	-5.8	1.3	7.4	0.9
France	5.3	2.9	0.5	0.8	1.1	-0.2	2.6	-3.6	-1.8	-1.0	2.2	-3.5	1.5	3.3	2.6
Germany	0.1	0.2	0.3	0.1	1.2	-1.5	1.2	-1.3	-1.5	-0.6	1.5	-1.8	1.7	1.1	0.1
Greece	3.6	-0.3	-0.1	-0.2	1.9	-2.5	2.8	-2.3	-1.0	-1.4	2.6	-5.8	1.1	5.7	0.5
Hungary	4.8	-2.5	-1.2	-1.0	0.3	-1.2	-0.5	-2.8	-0.7	-1.1	2.8	-4.4	2.6	10.6	-0.6
Ireland	1.9	-2.5	-0.6	-1.4	3.2	-6.0	2.1	-4.0	-2.3	-2.3	2.6	-6.0	1.1	5.1	3.2
Italy	2.9	-0.2	0.4	-0.1	1.1	-2.0	0.6	1.1	0.3	0.5	1.7	-0.7	3.4	1.0	0.9
Latvia	10.2	-2.4	-1.0	-0.8	1.5	-2.3	1.2	-11.9	-4.9	-3.8	3.3	-7.2	1.3	27.9	-3.5
Lithuania	16.8	0.4	1.5	0.7	7.7	-10.2	11.1	-15.8	-2.8	-3.7	2.0	-7.0	-2.0	36.9	-4.6
Luxembourg	12.9	2.0	0.6	0.9	2.1	-1.3	4.3	3.5	2.3	1.6	4.5	-3.6	6.3	4.2	3.3
Malta	9.4	10.6	5.7	6.1	13.0	-9.0	19.6	-3.0	-1.7	-1.3	15.2	-16.3	18.0	0.0	1.8
Netherlands	3.3	0.7	0.4	0.3	0.8	-0.5	1.4	-0.4	-0.5	-0.1	2.1	-2.6	3.2	1.7	1.2
Poland	1.2	-1.2	-0.1	-0.8	1.5	-3.4	0.5	-2.4	-1.4	-1.5	1.1	-3.1	-0.1	4.8	-0.1
Portugal	3.2	0.8	0.7	0.4	2.0	-2.9	2.2	0.5	0.3	0.2	1.2	-1.3	1.6	1.0	0.9
Romania	2.7	-1.1	0.0	-0.4	3.5	-5.1	4.4	-8.7	-4.3	-4.0	1.9	-5.8	-1.5	14.8	-2.2
Slovakia	3.0	1.7	-0.2	0.7	2.1	-1.1	4.1	-11.2	-3.7	-4.4	3.7	-9.9	0.1	12.5	-0.1
Slovenia	6.3	1.2	0.7	0.5	1.9	-2.6	2.2	-3.6	-1.3	-1.5	2.2	-4.6	0.9	8.5	0.2
Spain	7.2	-1.1	-0.6	-0.5	1.7	-2.1	1.5	0.5	0.3	0.2	1.5	-1.4	2.4	4.0	3.8
Sweden	7.7	9.9	1.3	2.1	3.4	-1.3	6.8	-14.9	-3.4	-3.0	1.5	-4.8	-0.9	11.0	1.8
UK	-0.1	0.6	0.3	0.3	0.9	-0.9	1.5	-6.8	-3.0	-3.2	1.0	-4.6	-2.0	5.1	1.1
EU-15	*2.4*	*0.5*	*0.2*	*0.2*	*0.4*	*-0.5*	*0.6*	*-2.2*	*-1.5*	*-0.9*	*1.4*	*-2.2*	*1.0*	*2.9*	*1.3*
EU-28	*2.5*	*0.2*	*0.0*	*0.1*	*0.4*	*-0.4*	*0.7*	*-2.1*	*-1.4*	*-0.9*	*1.3*	*-2.3*	*1.0*	*3.6*	*0.8*

Table 4. Results of total primary energy supply (ΔTPES) decomposition analysis for EU-28 Member States, 2005-2010. Cumulative effects are sums of incremental (annual) effects.

EU-28 Member State	ΔTPES 2005-2010, % of 2005 TPES	Cumulative TPES/FEC effect, % of 2005 TPES	Statistical info on incremental TPES/FEC effects, % of previous year's TPES					Cumulative FEC/GDP effect, % of 2005 TPES	Statistical info on incremental FEC/GDP effects, % of previous year's TPES					Cumulative GDP/POP effect, % of 2005 TPES	Cumulative POP effect, % of 2005 TPES
			Md	Av.	Stdev	Min	Max		Md	Av.	Stdev	Min	Max		
Austria	0.5	-0.3	0.4	-0.1	1.6	-2.7	1.6	-2.1	-0.6	-0.9	3.5	-5.2	3.3	2.2	0.7
Belgium	2.1	-0.4	0.8	-0.2	2.5	-4.3	2.3	-1.0	-3.3	-0.3	5.7	-5.5	6.3	1.4	2.1
Bulgaria	-4.4	0.7	-0.7	0.4	1.8	-1.1	3.3	-11.3	-5.8	-5.2	4.1	-10.2	0.2	8.1	-1.9
Croatia	-1.7	-1.1	-1.0	-0.5	2.8	-4.3	3.2	-1.7	-0.4	-0.8	2.8	-4.0	2.4	1.3	-0.2
Cyprus	3.1	0.6	1.9	0.5	2.5	-3.0	2.8	-1.6	-1.4	-1.0	1.6	-2.8	1.1	0.1	4.0
Czech	-0.5	1.4	1.5	0.8	2.7	-2.6	3.5	-6.6	-2.3	-3.4	3.6	-8.4	-0.1	3.6	1.1
Denmark	1.2	0.8	-0.2	0.5	3.3	-2.7	6.1	0.2	-0.5	0.1	2.4	-2.7	3.9	-0.8	0.9
Estonia	2.4	3.3	0.5	2.3	6.0	-2.8	11.3	-0.4	1.4	-0.3	5.6	-9.5	4.5	0.2	-0.7
Finland	4.2	1.4	-0.3	0.5	2.2	-1.6	3.9	-0.2	0.9	0.1	4.6	-4.8	6.8	1.6	1.4
France	-2.5	0.5	0.2	0.1	0.3	-0.4	0.4	-5.8	-1.6	-1.6	2.1	-3.9	1.1	0.7	2.0
Germany	-1.3	-0.9	-1.1	-0.5	1.3	-1.8	1.0	-3.0	0.5	-1.3	4.7	-9.3	2.3	3.0	-0.4
Greece	-2.8	-0.7	-0.6	-0.5	2.4	-2.9	3.5	-1.7	-1.5	-1.1	1.8	-2.9	1.6	-0.5	0.2
Hungary	-3.4	1.3	0.5	0.5	1.9	-2.1	2.7	-4.5	-1.6	-1.8	3.5	-5.4	2.6	0.2	-0.4
Ireland	-0.3	1.7	1.0	1.0	4.7	-3.7	6.0	-2.3	-1.2	-1.4	4.6	-8.1	4.6	-2.8	3.1
Italy	-3.0	-0.5	-0.1	-0.2	1.0	-1.3	1.2	-2.0	0.0	-1.0	2.5	-3.9	1.8	-1.6	1.1
Latvia	-0.3	-0.5	-0.3	-0.1	1.0	-1.4	1.0	1.9	-0.8	0.7	9.2	-7.6	15.6	2.2	-3.9
Lithuania	-14.7	-14.9	-4.4	-4.4	11.4	-21.9	7.2	-3.3	0.1	-0.8	3.6	-6.2	3.1	8.5	-4.9
Luxembourg	-1.5	-0.1	-0.3	0.0	0.7	-0.8	1.1	-5.5	-1.8	-2.9	4.2	-8.6	1.3	1.2	3.0
Malta	-2.2	-10.2	-5.7	-6.3	12.3	-24.6	9.3	4.3	1.0	2.7	9.2	-7.7	16.4	2.2	1.5
Netherlands	3.1	-0.9	0.5	-0.4	3.3	-5.8	2.7	0.3	-1.1	0.2	5.6	-7.2	6.6	2.8	0.9
Poland	2.8	-1.3	-1.1	-0.8	1.2	-2.3	0.5	-3.4	-2.9	-2.1	3.8	-6.0	4.1	7.2	0.3
Portugal	-4.8	-1.7	-1.3	-0.8	2.5	-3.6	1.8	-4.4	-1.7	-2.1	2.7	-5.2	1.0	1.0	0.3
Romania	-3.9	0.3	0.4	0.2	2.3	-3.2	2.8	-10.4	-4.7	-4.9	3.7	-8.2	0.9	8.4	-2.2
Slovakia	-2.7	-1.5	0.1	-0.6	2.8	-5.4	1.7	-12.3	-3.0	-4.9	4.6	-10.7	0.6	10.8	0.4
Slovenia	-0.3	-0.1	-0.6	-0.1	1.3	-1.3	1.4	-4.2	-2.7	-1.7	4.8	-8.1	3.0	2.9	1.2
Spain	-4.3	-0.1	-0.9	-0.1	1.7	-1.5	2.6	-6.5	-3.7	-3.0	3.2	-6.8	1.4	-0.4	2.7
Sweden	-1.4	-2.2	-0.8	-0.4	3.2	-4.8	3.1	-7.4	-2.8	-1.4	3.4	-5.4	2.9	4.3	3.8
UK	-3.8	-0.7	-1.0	-0.3	1.3	-1.4	1.7	-4.3	-3.1	-2.1	3.4	-5.1	2.8	-0.3	1.5
EU-15	*-2.0*	*-0.5*	*-0.3*	*-0.2*	*0.5*	*-0.6*	*0.5*	*-3.3*	*-0.9*	*-1.4*	*2.8*	*-4.4*	*2.5*	*0.6*	*1.2*
EU-28	*-1.7*	*-0.5*	*-0.3*	*-0.2*	*0.5*	*-0.6*	*0.6*	*-3.3*	*-1.1*	*-1.4*	*2.7*	*-4.4*	*2.4*	*1.3*	*0.8*

Table 5. Results of total primary energy supply (∆TPES) decomposition analysis for EU-28 Member States, 2010-2013. Cumulative effects are sums of incremental (annual) effects.

EU-28 Member State	∆TPES 2010-2013, % of 2010 TPES	Cumulative TPES/FEC effect, % of 2010 TPES	Statistical info on incremental TPES/FEC effects, % of previous year's TPES					Cumulative FEC/GDP effect, % of 2010 TPES	Statistical info on incremental FEC/GDP effects, % of previous year's TPES					Cumulative GDP/POP effect, % of 2010 TPES	Cumulative POP effect, % of 2010 TPES
			Md	Av.	Stdev	Min	Max		Md	Av.	Stdev	Min	Max		
Austria	-1.3	-0.8	-0.8	-0.6	1.1	-1.5	0.6	-2.5	0.0	-1.7	4.3	-6.6	1.5	1.3	0.7
Belgium	-4.6	-2.1	-0.9	-1.2	1.1	-2.5	-0.3	-3.6	-3.2	-1.9	5.6	-6.8	4.2	0.0	1.2
Bulgaria	-2.2	-2.1	-3.2	-1.6	3.3	-3.9	2.2	-1.5	-1.1	-1.2	4.6	-5.8	3.4	2.2	-0.7
Croatia	-4.6	-0.4	-0.7	-0.3	0.9	-1.0	0.8	-2.7	-1.9	-2.0	1.4	-3.3	-0.6	0.2	-1.7
Cyprus	-7.0	-0.5	0.1	-0.6	4.2	-5.1	3.3	-4.3	-3.3	-4.5	2.1	-6.8	-3.2	-4.1	1.9
Czech	-2.2	-0.6	-0.1	-0.5	1.2	-1.8	0.4	-1.8	-0.1	-1.5	3.4	-5.4	0.9	0.2	0.0
Denmark	-4.3	-0.5	0.0	-0.3	2.5	-2.9	2.0	-3.8	-3.1	-3.2	2.5	-5.8	-0.8	-0.4	0.4
Estonia	2.5	2.0	3.3	2.3	5.8	-4.0	7.5	-3.7	-2.4	-4.1	6.3	-11.1	1.1	4.5	-0.2
Finland	-5.7	-1.9	-1.0	-1.1	3.1	-4.3	1.9	-3.8	-0.4	-2.1	5.4	-8.2	2.2	-0.9	0.8
France	-2.5	-0.4	-1.4	-0.2	3.1	-2.6	3.3	-4.1	1.5	-1.7	6.4	-9.1	2.5	1.0	1.1
Germany	-1.2	-0.4	-0.3	-0.4	0.1	-0.4	-0.3	-2.4	0.3	-1.9	5.4	-8.0	2.1	1.5	0.2
Greece	-5.0	2.4	-1.0	2.5	6.4	-1.3	10.0	-1.1	-3.9	-1.2	7.3	-6.8	7.0	-6.1	-0.3
Hungary	-6.6	-1.8	-0.6	-1.2	3.9	-5.4	2.3	-5.7	-3.9	-3.6	3.2	-6.6	-0.2	1.5	-0.6
Ireland	-3.5	0.3	0.3	0.3	1.4	-1.2	1.7	-4.6	-1.4	-4.3	6.4	-11.5	0.2	0.6	0.3
Italy	-3.7	-0.8	-0.1	-0.6	1.7	-2.5	0.7	-1.3	-1.9	-1.0	2.6	-3.1	1.9	-2.2	0.6
Latvia	-2.0	1.2	-0.1	0.7	1.5	-0.1	2.5	-10.8	-8.1	-6.5	4.8	-10.4	-1.1	10.0	-2.4
Lithuania	-0.7	-3.3	-1.1	-1.9	2.5	-4.6	0.1	-4.9	-1.6	-2.7	5.7	-8.8	2.4	10.3	-2.7
Luxembourg	-2.3	-1.0	-0.9	-0.8	0.9	-1.6	0.1	-3.1	-2.6	-2.6	0.8	-3.5	-1.9	-1.2	2.9
Malta	-3.5	-4.4	0.0	-4.3	8.3	-13.9	1.1	-0.8	-1.3	-0.7	4.4	-4.8	4.0	1.7	0.0
Netherlands	-3.6	-1.2	-0.6	-0.9	1.5	-2.5	0.5	-2.1	1.7	-1.3	7.0	-9.3	3.7	-0.8	0.5
Poland	-0.9	0.8	1.4	0.9	3.2	-2.5	3.8	-4.3	-3.1	-4.5	2.9	-7.8	-2.5	2.6	0.0
Portugal	-3.6	3.7	2.8	2.6	1.0	1.5	3.5	-3.8	-2.4	-2.6	2.1	-4.8	-0.6	-3.1	-0.5
Romania	-4.3	-3.5	-3.5	-2.4	2.3	-4.1	0.2	-3.6	-0.3	-2.6	5.4	-8.8	1.3	3.4	-0.6
Slovakia	-1.8	1.0	1.4	0.6	2.7	-2.4	2.8	-5.6	-6.8	-3.6	6.8	-8.3	4.2	3.0	-0.2
Slovenia	-2.6	-0.2	-0.5	-0.1	1.8	-1.8	1.8	-1.0	-0.8	-0.7	1.3	-2.0	0.7	-1.6	0.2
Spain	-4.2	1.7	2.1	1.2	4.1	-3.3	4.7	-4.0	-2.7	-2.8	0.3	-3.1	-2.5	-1.9	0.0
Sweden	-3.6	4.6	0.9	1.4	1.7	0.1	3.3	-12.1	-3.1	-3.7	4.1	-8.0	0.1	1.4	2.5
UK	-2.4	0.2	0.6	0.1	1.5	-1.6	1.4	-4.2	-1.1	-3.3	6.2	-10.2	1.5	0.7	0.9
EU-15	-2.8	*-0.1*	*-0.2*	*-0.1*	*1.0*	*-1.0*	*1.0*	-3.2	*0.0*	*-2.2*	*4.2*	*-7.0*	*0.5*	*0.0*	*0.5*
EU-28	-2.7	*-0.1*	*-0.4*	*-0.1*	*1.1*	*-1.0*	*1.2*	-3.2	*-0.3*	*-2.2*	*3.8*	*-6.6*	*0.2*	*0.3*	*0.3*

In Tables 2-5, the most decreasing and the most increasing values for the effects of TPES/FEC and FEC/GDP have been marked with different shades of green (decreasing effect) and red (increasing effect). The scales of the shades are based on the following decrease/increase categories:

-20.00% or more	bright green
-19.99%...-10.00%	green
-9.99%...-2.50%	light green
-2.49% – 2.49%	white
2.50%...9.99%	light red
10.00%...19.99%	red
20.00% or more	bright red

In the sense how changes in energy efficiency related indicators TPES/FEC and FEC/GDP have contributed to change in total primary energy supply (ΔTPES), the performance of EU Member States as well as the performance of the EU as a whole has been very different during the four different time periods, 1990-2000, 2000-2005, 2005-2010 and 2010.2013.

4.1. TPES decomposition results, EU-28 Member States 1990-2000

In the first time period 1990-2000 (Table 2), total primary energy supply increased in 17 Member States and also at the aggregate levels of EU-15 (4.3%) and EU-28 (1.2%). Large increase took place in Portugal (20.6%), Cyprus (19.8%), Spain (15.7%) and Ireland (12.9%). Total primary energy supply decreased in 11 Member States, larges decreases took place in Lithuania (-27.7%), Latvia (-21.4%), Romania (-15.5%), Estonia (14.1%) and Bulgaria (-12.9%). Generally speaking, TPES increased especially in the Mediterranean Member States and decreased in the Baltic and East European Member States. Among the large EU Member States, changes were quite modest, TPES increased in France (8.1%), the UK (3.1%) and Italy (1.8%), and decreased in Germany (-1.6%).

The change in energy intensity (FEC/GDP) had a decreasing effect in 22 Member States and increasing effect in six Member States, i.e. in Portugal, Spain Bulgaria, Cyprus, Slovenia and Belgium (Table 2). Decreasing effect was relatively large (compared to the 1990 absolute TPES value) in Lithuania (-16.0%), Bulgaria (-15.2%), Slovakia (-13.2%), Estonia (-12.9%), Ireland (-12.4%), Poland (-11.9%), Sweden (-11.7%), Romania (-11.3%), Malta (-11.0%), and Luxembourg (-10.2%). From these Member States, in Bulgaria, Estonia and Romania the change in TPES was also large. At the EU aggregate level, change in energy intensity had a modest decreasing effect, -5.3% in EU-15 and -7.3% in EU-28. An interesting observation is that the incremental (annual) change in energy intensity had a large variation in values (large difference in minimum and maximum values and large standard deviation) in those Member States with large decrease in total primary energy supply. The Member States with large increase in TPES had much smaller difference in minimum and maximum values as well as smaller standard deviation of FEC/GDP.

The change in efficiency of the energy transformation process (TPES/FEC) had a decreasing effect in 18 Member States (Table 2). The larges decreasing effects were in Sweden (-8.0%), Malta (-5.7%), Luxembourg (-5.2%), and Slovenia (-5.0%). In most of the Member States with decreasing TPES/FEC effect, however, total primary energy supply increased during the years 1990-2000. Change in TPES/FEC decreased total primary energy supply also in the EU aggregates, -0.5% in EU-15 and the same in EU-28. When looking at the annual changes, Member States such as Malta, Cyprus, Romania and Sweden had large difference in minimum and maximum values and large standard deviation of TPES/FEC with very different change of TPES in percentage (-0.4%, 19.8%, -15.5% and 0.7%, respectively.

EU Member States with a decrease in total primary energy supply (TPES) and decreasing effect in both energy efficiency related drivers in the time period 1990-2000, included Latvia, Poland, Germany, Malta, and Luxembourg. Unlike the others, during this 10-year period Latvia suffered from a decreasing effect of economic growth (GDP/POP).

4.2. TPES decomposition results, EU-28 Member States 2000-2005

In the second time period 2000-2005 (Table 3), total primary energy supply (TPES) increased even more, in 27 Member States and in the EU aggregates (2.4% in EU-15 and 2.5% in EU-28, from the absolute TPES value in the year 2000). TPES increase was large in Lithuania (16.8%), Luxembourg (12.9%) and Latvia (10.2%), totally different Member States than in the previous time period. Total primary energy supply decreased only in the UK, and even there very marginally (-0.1%). In France, Germany, and Italy TPES increased 5.3%, 0.1%, and 2.9%, respectively.

Change in energy intensity (FEC/GDP) had in the period 2000-2005 a decreasing effect on TPES in 23 EU Member States (Table 3). A small increasing effect took place in four Member States, i.e. in Austria, Italy, Portugal and Spain, and there was no effect in Belgium. Decreasing effect was large in Lithuania (-15.9%), Sweden (-14.9%), Latvia (-11.9%) and Slovakia (-11.2%). Large Member States France, Germany, and the UK had decreasing effects -3.6%, -1.3%, and -6.8%, respectively. At the aggregate level, change in energy intensity had a decreasing effect, -2.2% in EU-15 and -2.1% in EU-28. Regarding the incremental (annual) values of FEC/GDP change, variation in terms of standard deviation and difference between minimum and maximum values was the largest in Malta.

Change in the efficiency of the energy transformation system (TPES/FEC) decreased total primary energy supply in 13 EU Member States in the period 2000-2005 (Table 3), but the decreasing effects were in all cases only modest, Hungary and Ireland had the largest effects, both -2.5%. The UK was the only one of the large Member States with a decreasing effect (-0.2%). Increasing effects were the largest in Malta (10.6% and Sweden (9.9%). Large Member States France, Germany, and the UK had increasing effects 2.9%, 0.2%, and 0.6%, respectively. EU aggregates had small increasing effects, 0.5% in EU-15 and 0.2% in EU-28. Large variation in annual (incremental) effects took place in Malta and Lithuania.

In general, 2000-2005 was a poor period in terms of impacts of energy efficiency on total primary energy supply, although there were decreasing effects in both of the energy efficiency related drivers in many EU Member States. However, none of the Member States reached a situation where decreasing effects in both energy efficiency related drivers were combined to a decrease in total primary energy supply (TPES) during the period 2000-2005.

4.3. TPES decomposition results, EU-28 Member States 2005-2010

In the third time period 2005-2010 (Table 4), total primary energy supply (TPES) decreased in 20 EU Member States and increased in 8 Member States. Largest decreases took place in Lithuania (-14.7%), while in all the others decrease was only modest varying between -4.8% and -0.3%. TPES increases were also modest ones varying between 0.5% and 4.2%. The large EU Member States France, Germany, Italy, and the UK all had a decrease of TPES in 2005-2010; -2.5%, -1.3%, -3.0%, and -3.8%, respectively. At the EU aggregate level, TPES change was -2.0% in EU-15 and -1.7% in EU-28.

Change in energy intensity (FEC/GDP) had a decreasing effect on TPES in 23 Member States in 2005-2010 (Table 4). Large effects were in Slovakia (-12.3%), Bulgaria (-11.3%), and Romania (-10.4%). In other Member States, the decreasing TPES change varied between -7.4% and -0.2%. All the large Member States (France, Germany, Italy, and the UK) had a modest decreasing FEC/GDP effect. The increasing effect in five Member States varied modestly between 0.2% and 4.3%. In both EU aggregates, energy intensity had a -3.3% decreasing effect on TPES. Malta, Latvia, Slovakia and Bulgaria had the largest variation in incremental (annual) FEC/GDP effects.

Change in efficiency of the energy transformation system (TPES/FEC) had a decreasing effect on TPES in 18 Member States but a significant one in Lithuania (-14.9%) and Malta (-10.2%) only (Table 4). These Member States had also a large variation in incremental (annual) effects (large standard deviation and large difference in minimum and maximum values). In other Member States, the decreasing FEC/GDP effect varied between -2.2% and -0.1%. The increasing effect of TPES/FEC in 10 Member States varied between 0.3% and 1.7%. At the EU aggregate level, the effect of TPES/FEC was a decreasing one, -0.5% both in EU-15 and EU-28. The large Member States were close to these figures, even France with an increasing effect of 0.5%. Large variation in incremental (annual) TPES/FEC effects (large standard deviation and large difference between minimum and maximum values) can be identified in Malta, Lithuania and Estonia.

In general, 2005-2010 was quite a good time period in terms of energy efficiency impact on total primary energy supply. 10 Member States, i.e. Croatia, Greece, Italy, Lithuania, Luxembourg, Portugal, Slovakia, Spain, Sweden, and the UK, as well as both EU aggregates EU-15 and EU-28, had a decrease in TPES and decreasing effect in both energy efficiency related drivers, FEC/GDP and TPES/FEC.

4.4. TPES decomposition results, EU-28 Member States 2010-2013

In the most recent time period 2010-2013 (Table 5), total primary energy supply (TPES) decreased in all EU Member States except Estonia, where TPES increased 2.5%. Decrease in this short 3-year time period varied between -7.0% and -0.7%. In the whole EU, decrease was -2.8% in EU-15 and -2.7% in EU-28. All large EU member States France, Germany, Italy, and the UK were close to these EU-level decreasing effects.

Change in the energy intensity (FEC/GDP) decreased total primary energy supply (TPES) in all 28 EU Member States during 2010-2013 (Table 5). Sweden (-12.1%) and Latvia (-10.8%) had the largest decreasing effects, while in other Member States, including the large ones, the value varied between -5.7% and -0.8%. The EU aggregate value was -3.2% for both EU-15 and EU-28. Regarding the annual (incremental) effects, quite a large variation took place during this time period in Estonia, Ireland, Latvia, and the UK.

Change in efficiency of the energy transformation system (TPES/FEC) had a decreasing effect in 18 EU Member States, the values varying between -6.6% and -0.2% from the absolute TPES value in 2010 (Table 5). Increasing effect in 10 Member States varied between 0.2% and 4.6%. EU-15 and EU-28 had both a TPES/FEC effect value -0.1%. Malta and Greece had a large variation in the incremental (annual) values of the TPES/FEC effect in terms of standard deviation and difference between the minimum and maximum values.

The most recent time period 2010-2013 was the shortest but also best in terms of the effects of energy intensity related drivers on total primary energy supply (TPES). 18 out of 28 EU Member States had a decrease in TPES and also a decreasing effect of both energy intensity related drivers, FEC/GDP and TPES/FEC.

5. Decomposition of carbon dioxide emissions from fuel combustion

Another major policy target in relation to improving energy efficiency, is to reduce greenhouse gas emissions from energy use. The current EU target for greenhouse gas emissions in the UNFCCC process, 20% reduction by the year 2020, is related to the 1990 emission level.

In the following, as indicator of greenhouse gas emissions, carbon dioxide emissions from fuel combustion (CO2) will be used. These emissions cover about 80% of all greenhouse gas emissions in the European Union. Thus, climate targets are directly linked to energy efficiency by this indicator. CO2 emissions from fuel combustion will be decomposed into the relative contributions of drivers described above in Equation 12, i.e. CO2/TPES, TPES/FEC, FEC/GDP, GDP/POP and POP. Data used in this decomposition activity is taken from the International Energy Agency online database (IEA 2015). This data includes carbon dioxide (CO2) emissions from fuel combustion, total primary energy supply (TPES), final energy consumption (FEC), gross domestic product (GDP) in real prices (in 2005 USD, adjusted by exchange rates), and number of population. The data used in the analyses covers the years 1990-2013, and it is the most recent data available from International Energy Agency.

The results are based on an analysis of incremental (annual) changes, and they are always presented as percentage of a selected base year value of the decomposed indicator, i.e. total primary energy supply (TPES). Tables 6-9 show results from analyses carried out for the years 1990-2013, divided into four time periods: 1990-2000 (Table 6), 2000-2005 (Table 7), 2005-2010 (Table 8) and 2010-2013 (Table 9). The main results are the effects of the energy efficiency related drivers TPES/FEC and FEC/GDP as well as other drivers defined in Equation 12 above, i.e. CO2/TPES, GDP/POP and POP, to the change in carbon dioxide emissions from fuel combustion (ΔCO2). The incremental changes are summed up for each time period and presented as percentage from the absolute CO2 value of the first year of teach time period. In Tables 6-9, for the energy efficiency related drivers (TPES/FEC and FEC/GDP), basic statistical info (median, average, standard deviation and minimum and maximum values) on the annual effects during each of the selected time periods (as percentage of the previous year's CO2 value) are presented as well. Appendix 1 incudes charts describing the results of all incremental decompositions of ΔCO2 (and ΔTPES, see Chapter 4) for each EU-28 Member State and for EU-15 and EU-28 aggregates during the time period 1990-2013.

Table 6. Results of carbon dioxide emissions from fuel combustion (ΔCO2) decomposition analysis for EU-28 Member States, 1990-2000. Cumulative effects are sums of incremental (annual) effects.

EU-28 Member State	**ΔCO2 1990-2000, % of 1990 CO2**	**Cumulative TPES/FEC effect, % of 1990 CO2**	***Statistical info on incremental TPES/FEC effects, % of previous year's CO2***					**Cumulative FEC/GDP effect, % of 1990 CO2**	***Statistical info on incremental FEC/GDP effects, %/a***					**Cumulative CO2/TPES effect, % of 1990 CO2**	**Cumulative GDP/POP effect, % of 1990 CO2**	**Cumulative POP effect, % of 1990 CO2**
			Md	***Av.***	***Stdev***	***Min***	***Max***		***Md***	***Av.***	***Stdev***	***Min***	***Max***			
Austria	9.8	-4.2	-0.4	-0.4	1.3	-2.3	2.4	-8.7	-2.1	-0.8	3.7	-5.0	6.1	-4.9	23.3	4.3
Belgium	7.4	-6.6	-0.5	-0.7	1.1	-3.0	1.1	3.3	-0.4	0.4	3.3	-4.6	5.6	-12.9	20.8	2.9
Bulgaria	-43.4	14.1	2.2	1.8	3.6	-4.6	6.2	-38.4	-4.9	-4.7	6.7	-19.2	2.5	-10.4	-4.1	-4.7
Croatia	-18.3	-4.4	-0.8	-0.5	3.1	-5.2	4.7	5.2	-2.2	1.1	7.8	-7.8	18.7	-5.2	-7.4	-6.5
Cyprus	62.0	-3.7	2.3	-0.5	8.5	-16.1	10.1	7.4	-1.3	0.9	5.2	-3.4	14.0	2.8	30.8	24.6
Czech	-19.3	4.0	0.8	0.5	2.2	-3.7	3.1	-23.4	-2.6	-2.8	2.0	-6.8	-0.3	-2.1	2.9	-0.8
Denmark	-0.4	-0.6	-0.8	0.2	4.5	-4.8	9.4	-22.0	-3.0	-1.7	3.8	-5.7	5.0	-8.7	26.4	4.5
Estonia	-59.7	7.1	-0.4	0.7	4.4	-5.9	9.8	-42.2	-9.7	-7.3	9.0	-17.4	9.7	-10.5	-6.1	-7.9
Finland	1.6	3.5	0.1	0.4	3.6	-5.9	5.9	-14.5	-1.8	-1.3	3.9	-7.7	5.4	-12.4	21.1	3.9
France	5.5	-1.5	-0.2	-0.1	2.1	-2.6	3.6	-7.9	-1.2	-0.7	3.0	-3.5	6.1	-6.6	16.9	4.6
Germany	-13.6	-0.3	-0.3	0.0	0.8	-1.2	1.5	-21.8	-3.3	-2.3	2.8	-6.1	3.0	-9.6	14.8	3.3
Greece	25.9	-0.7	0.2	-0.1	2.2	-4.1	2.5	-0.3	-0.5	0.0	2.3	-4.1	4.3	-0.2	21.2	5.9
Hungary	-18.9	4.2	0.7	0.4	2.5	-3.5	4.0	-17.9	-2.8	-2.1	4.5	-9.3	6.4	-5.7	2.0	-1.4
Ireland	35.6	-3.5	0.0	-0.2	1.5	-3.6	1.8	-37.4	-3.0	-3.4	2.6	-8.4	0.1	-3.0	70.2	9.2
Italy	8.0	4.4	0.1	0.4	1.6	-1.1	4.2	-5.1	0.2	-0.5	1.8	-3.9	1.3	-8.2	16.5	0.4
Latvia	-63.6	-3.9	-0.5	-0.5	1.3	-2.7	1.6	-6.9	-7.9	-3.7	9.9	-10.9	18.6	-16.8	-29.3	-6.6
Lithuania	-68.3	5.6	2.2	0.4	6.9	-10.7	8.4	-25.2	-6.9	-4.5	9.1	-19.0	12.0	-19.6	-26.7	-2.4
Luxembourg	-25.0	-14.2	-1.2	-1.6	1.3	-3.8	-0.1	-27.7	-2.8	-3.2	3.1	-8.6	1.7	-23.9	28.2	12.5
Malta	-7.8	-19.0	-4.6	-1.5	11.8	-18.8	18.6	-35.8	-4.4	-3.2	10.1	-19.8	10.9	-6.6	45.0	8.5
Netherlands	8.5	-3.7	-0.4	-0.4	1.2	-2.0	1.3	-18.9	-1.7	-1.7	3.5	-6.8	5.1	-3.0	27.3	6.8
Poland	-16.0	-8.9	0.0	-0.9	1.9	-5.0	0.7	-39.3	-6.0	-4.1	6.2	-11.6	7.8	-2.3	33.9	0.6
Portugal	52.7	1.1	0.1	0.2	3.7	-4.7	7.1	10.6	1.1	0.9	2.2	-3.5	4.0	4.7	32.3	3.9
Romania	-48.8	4.9	-0.2	0.4	5.9	-9.6	10.9	-29.1	-4.8	-4.0	6.2	-11.2	8.1	-9.0	-13.1	-2.5
Slovakia	-32.7	12.0	0.9	1.3	3.6	-4.3	8.6	-31.1	-2.9	-4.0	4.2	-12.3	0.3	-16.2	1.2	1.4
Slovenia	3.8	-11.7	-1.4	-1.2	2.6	-6.0	3.1	3.7	-1.1	0.5	5.2	-4.9	9.6	-8.5	20.8	-0.5
Spain	37.5	-4.7	-0.3	-0.4	1.3	-2.1	2.0	7.6	1.5	0.7	1.8	-2.0	3.0	2.4	28.5	3.7
Sweden	-0.2	-9.1	-0.4	-0.9	4.1	-10.6	4.1	-13.0	-1.6	-1.1	4.1	-5.9	7.1	-1.2	19.4	3.8
UK	-4.8	-0.7	0.0	-0.1	0.8	-1.5	1.0	-14.0	-1.5	3.2	-4.9	5.4	-2.3	-12.6	19.7	2.7
EU-15	*1.4*	*-1.2*	*-0.1*	*-0.1*	*0.4*	*-0.5*	*0.6*	*-11.7*	*-1.2*	*1.7*	*-3.0*	*1.8*	*-1.6*	*-8.2*	*19.2*	*3.3*
EU-28	*-6.0*	*-1.1*	*-0.1*	*-0.1*	*0.4*	*-0.6*	*0.8*	*-16.9*	*-1.8*	*1.8*	*-3.3*	*2.0*	*-2.6*	*-8.7*	*18.6*	*2.0*

Table 7. Results of carbon dioxide emissions from fuel combustion (ΔCO_2) decomposition analysis for EU-28 Member States, 2000-2005. Cumulative effects are sums of incremental (annual) effects.

EU-28 Member State	ΔCO_2 2000-2005, % of 2000 CO_2	Cumulative TPES/FEC effect, % of 2000 CO_2	*Statistical info on incremental TPES/FEC effects, % of previous year's CO_2*					Cumulative FEC/GDP effect, % of 2000 CO_2	*Statistical info on incremental FEC/GDP effects, %/a*					Cumulative CO_2/TPES effect, % of 2000 CO_2	Cumulative GDP/POP effect, % of 2000 CO_2	Cumulative POP effect, % of 2000 CO_2
			Md	*Av.*	*Stdev*	*Min*	*Max*		*Md*	*Av.*	*Stdev*	*Min*	*Max*			
Austria	21.7	0.6	0.2	0.1	0.4	-0.4	0.5	8.5	0.7	1.6	3.0	-1.1	4.9	2.8	6.7	3.1
Belgium	-5.9	0.0	0.9	0.0	1.6	-2.3	1.4	-8.1	-2.1	-1.6	3.4	-6.3	2.2	-6.2	6.3	2.1
Bulgaria	10.2	-1.8	0.4	-0.3	3.7	-5.3	4.1	-18.3	-3.8	-3.4	4.3	-8.4	2.4	3.1	32.9	-5.7
Croatia	18.7	-2.8	-0.7	-0.4	2.1	-3.6	1.5	-7.1	-2.7	-1.3	2.2	-3.1	2.0	3.7	24.7	0.2
Cyprus	11.9	-6.8	-0.6	-1.2	5.1	-9.2	4.8	-6.4	-1.5	-1.2	2.3	-3.2	2.2	8.2	10.9	5.9
Czech	-2.4	2.1	0.0	0.4	1.7	-1.0	3.4	-11.9	-1.5	-2.4	3.1	-6.8	1.1	-11.7	19.5	-0.4
Denmark	-4.6	-3.2	0.4	-0.5	3.2	-4.2	3.6	-2.0	-1.4	-0.4	2.0	-2.0	1.9	-6.3	5.4	1.5
Estonia	15.9	-7.3	-2.7	-1.3	4.2	-4.6	5.8	-19.4	-2.7	-3.6	4.7	-9.1	3.0	5.1	40.6	-3.1
Finland	0.3	3.2	1.3	0.7	3.1	-4.2	4.1	-10.7	-1.2	-1.7	2.6	-5.5	1.3	-7.1	13.4	1.6
France	1.5	4.0	0.5	0.8	1.1	-0.2	2.6	-4.9	-1.8	-1.0	2.2	-3.4	1.5	-5.8	4.6	3.7
Germany	-3.2	0.4	0.3	0.1	1.2	-1.5	1.2	-3.1	-1.5	-0.6	1.5	-1.7	1.7	-3.3	2.5	0.3
Greece	8.2	-0.8	-0.1	-0.2	1.9	-2.5	2.8	-7.4	-1.0	-1.4	2.6	-5.7	1.1	-3.3	18.1	1.6
Hungary	2.7	-5.3	-1.2	-1.0	0.3	-1.2	-0.5	-6.1	-0.7	-1.1	2.7	-4.3	2.6	-7.3	22.5	-1.2
Ireland	8.4	-7.4	-0.6	-1.4	3.2	-6.1	2.1	-11.7	-2.4	-2.3	2.6	-5.9	1.1	2.7	15.3	9.4
Italy	8.6	-0.5	0.4	-0.1	1.1	-2.0	0.6	2.8	0.3	0.5	1.7	-0.7	3.4	1.4	2.6	2.3
Latvia	10.8	-4.1	-1.0	-0.8	1.5	-2.4	1.2	-20.3	-4.9	-3.7	3.3	-7.2	1.3	-7.0	48.3	-6.0
Lithuania	20.1	0.9	1.4	0.4	7.8	-10.9	10.6	-19.8	-3.0	-3.7	1.9	-6.9	-1.9	-2.0	46.7	-5.8
Luxembourg	42.4	4.9	0.6	0.9	2.1	-1.3	4.4	8.9	2.3	1.6	4.6	-3.6	6.3	9.6	10.6	8.4
Malta	27.7	33.1	5.7	6.1	13.0	-9.0	19.7	-9.2	-1.7	-1.3	15.2	-16.2	17.9	-1.8	-0.2	5.7
Netherlands	3.9	1.6	0.4	0.3	0.8	-0.5	1.4	-0.7	-0.5	-0.1	2.1	-2.5	3.2	-3.2	3.6	2.6
Poland	2.3	-3.9	-0.1	-0.8	1.6	-3.4	0.5	-7.7	-1.4	-1.5	1.1	-3.1	-0.1	-1.5	15.6	-0.3
Portugal	6.1	1.9	0.7	0.4	2.0	-2.8	2.3	1.3	0.3	0.2	1.2	-1.3	1.6	-1.4	2.3	2.1
Romania	7.4	-2.7	0.0	-0.4	3.4	-5.1	4.3	-21.2	-4.4	-4.0	1.9	-5.7	-1.5	0.8	36.0	-5.4
Slovakia	1.0	3.5	-0.2	0.7	2.2	-1.1	4.2	-22.2	-3.7	-4.4	3.8	-10.0	0.1	-5.0	24.8	-0.2
Slovenia	9.9	2.6	0.7	0.5	1.9	-2.5	2.2	-7.8	-1.3	-1.5	2.2	-4.6	0.9	-3.7	18.3	0.5
Spain	19.8	-2.6	-0.6	-0.5	1.7	-2.1	1.5	1.0	0.3	0.2	1.5	-1.4	2.4	3.3	9.2	8.8
Sweden	-5.5	10.3	1.3	2.0	3.3	-1.3	6.5	-15.3	-3.3	-3.0	1.5	-4.6	-0.9	-13.7	11.3	1.8
UK	1.9	1.3	0.3	0.3	0.9	-0.9	1.5	-16.1	-3.0	-3.2	1.0	-4.5	-2.0	2.1	12.1	2.6
EU-15	*3.5*	*1.0*	*0.2*	*0.2*	*0.4*	*-0.5*	*0.6*	*-4.8*	*-1.5*	*-0.9*	*1.4*	*-2.2*	*1.0*	*-1.8*	*6.2*	*2.8*
EU-28	*3.5*	*0.6*	*0.0*	*0.1*	*0.4*	*-0.5*	*0.7*	*-4.7*	*-1.4*	*-0.9*	*1.3*	*-2.3*	*1.0*	*-2.1*	*7.9*	*1.8*

Table 8. Results of carbon dioxide emissions from fuel combustion (ΔCO2) decomposition analysis for EU-28 Member States, 2005-2010. Cumulative effects are sums of incremental (annual) effects.

EU-28 Member State	**ΔCO2 2005-2010, % of 2005 CO2**	**Cumulative TPES/FEC effect, % of 2005 CO2**	***Statistical info on incremental TPES/FEC effects, % of previous year's CO2***					**Cumulative FEC/GDP effect, % of 2005 CO2**	***Statistical info on incremental FEC/GDP effects, %/a***					**Cumulative CO2/TPES effect, % of 2005 CO2**	**Cumulative GDP/POP effect, % of 2005 CO2**	**Cumulative POP effect, % of 2005 CO2**
			Md	***Av.***	***Stdev***	***Min***	***Max***		***Md***	***Av.***	***Stdev***	***Min***	***Max***			
Austria	-7.1	-0.7	0.4	-0.1	1.6	-2.6	1.6	-4.7	-0.6	-0.9	3.4	-5.1	3.3	-8.0	4.8	1.5
Belgium	-5.1	-0.7	0.8	-0.2	2.5	-4.3	2.2	-2.1	-3.2	-0.2	5.7	-5.4	6.3	-8.4	2.5	3.6
Bulgaria	-4.5	1.8	-0.7	0.4	1.8	-1.0	3.3	-27.6	-5.7	-5.3	4.1	-10.2	0.2	6.2	19.6	-4.6
Croatia	-8.3	-2.5	-1.0	-0.5	2.8	-4.3	3.2	-4.0	-0.4	-0.8	2.8	-4.0	2.4	-4.7	3.2	-0.4
Cyprus	3.0	2.1	1.9	0.5	2.5	-3.0	2.7	-5.0	-1.4	-1.0	1.5	-2.8	1.1	-6.7	0.4	12.2
Czech	-5.9	3.7	1.5	0.8	2.7	-2.6	3.4	-17.1	-2.3	-3.4	3.6	-8.5	-0.1	-4.7	9.5	2.8
Denmark	-2.1	2.2	-0.2	0.5	3.4	-2.7	6.3	0.3	-0.5	0.1	2.4	-2.8	3.8	-5.2	-1.8	2.4
Estonia	10.9	10.4	0.5	2.5	6.2	-2.7	11.9	-0.9	1.5	-0.3	5.4	-9.2	4.4	2.9	0.6	-2.2
Finland	12.7	2.2	-0.3	0.5	2.3	-1.6	4.1	-0.8	0.9	0.2	4.7	-4.8	7.0	5.6	3.4	2.2
France	-8.1	0.6	0.2	0.1	0.3	-0.4	0.4	-7.8	-1.6	-1.6	2.1	-3.8	1.1	-4.7	1.0	2.7
Germany	-3.5	-2.1	-1.1	-0.5	1.3	-1.8	1.0	-7.0	0.5	-1.3	4.8	-9.3	2.3	-0.5	7.0	-0.8
Greece	-12.4	-2.3	-0.6	-0.5	2.4	-2.9	3.4	-5.4	-1.6	-1.1	1.8	-2.8	1.6	-3.9	-1.4	0.6
Hungary	-13.2	2.5	0.5	0.5	1.9	-2.1	2.7	-9.0	-1.6	-1.8	3.5	-5.4	2.5	-6.4	0.6	-0.8
Ireland	-11.1	4.8	1.0	1.0	4.6	-3.7	5.9	-6.8	-1.2	-1.3	4.5	-8.0	4.6	-10.2	-8.0	9.2
Italy	-14.1	-1.1	-0.1	-0.2	0.9	-1.2	1.2	-5.1	0.0	-1.0	2.5	-3.8	1.8	-6.7	-3.8	2.6
Latvia	6.7	-0.8	-0.3	-0.1	1.0	-1.4	1.0	2.9	-0.8	0.6	9.0	-7.7	15.2	7.2	4.0	-6.6
Lithuania	-0.7	-23.4	-4.2	-5.1	12.8	-25.6	7.1	-4.2	0.1	-0.8	3.6	-6.2	3.0	21.0	12.7	-6.8
Luxembourg	-7.2	-0.3	-0.3	0.0	0.7	-0.8	1.1	-14.3	-1.8	-2.9	4.1	-8.5	1.3	-3.4	3.2	7.5
Malta	-6.6	-31.6	-5.6	-6.3	12.2	-24.4	9.3	13.4	1.0	2.7	9.2	-7.7	16.3	0.2	6.7	4.6
Netherlands	3.1	-1.8	0.5	-0.4	3.3	-5.7	2.7	0.4	-1.1	0.1	5.6	-7.3	6.6	-3.1	5.9	1.7
Poland	4.8	-3.9	-1.1	-0.8	1.2	-2.3	0.5	-10.8	-2.8	-2.1	3.8	-6.0	4.1	-4.1	22.6	1.0
Portugal	-22.5	-3.7	-1.2	-0.8	2.5	-3.5	1.8	-9.7	-1.6	-2.1	2.7	-5.1	1.0	-11.9	2.2	0.6
Romania	-19.3	0.8	0.4	0.2	2.3	-3.2	2.8	-24.4	-4.7	-4.8	3.6	-8.1	0.9	-10.8	20.0	-5.0
Slovakia	-7.2	-3.0	0.1	-0.6	2.9	-5.5	1.7	-24.3	-3.0	-4.9	4.6	-10.6	0.6	-2.0	21.4	0.7
Slovenia	0.0	-0.1	-0.6	-0.1	1.3	-1.2	1.4	-9.1	-2.7	-1.7	4.8	-8.1	3.0	0.6	6.2	2.5
Spain	-21.5	0.0	-0.9	-0.1	1.6	-1.5	2.6	-14.9	-3.6	-3.0	3.1	-6.7	1.4	-12.1	-0.6	6.2
Sweden	-6.2	-2.0	-0.8	-0.4	3.2	-4.9	3.1	-6.9	-2.8	-1.3	3.4	-5.3	2.9	-5.1	4.3	3.4
UK	-10.3	-1.6	-1.1	-0.4	1.3	-1.4	1.7	-10.5	-3.1	-2.1	3.4	-5.1	2.8	-0.9	-0.8	3.6
EU-15	*-8.9*	*-1.0*	*-0.3*	*-0.2*	*0.5*	*-0.6*	*0.5*	*-7.1*	*-0.9*	*-1.4*	*2.8*	*-4.4*	*2.5*	*-4.6*	*1.4*	*2.4*
EU-28	*-7.8*	*-1.1*	*-0.3*	*-0.2*	*0.5*	*-0.6*	*0.6*	*-7.2*	*-1.1*	*-1.4*	*2.7*	*-4.4*	*2.4*	*-4.1*	*2.8*	*1.7*

Table 9. Results of carbon dioxide emissions from fuel combustion (ΔCO_2) decomposition analysis for EU-28 Member States, 2010-2013. Cumulative effects are sums of incremental (annual) effects.

EU-28 Member State	ΔCO_2 2010-2013, % of 2010 CO_2	Cumulative TPES/FEC effect, % of 2010 CO_2	*Statistical info on incremental TPES/FEC effects, % of previous year's CO_2*					Cumulative FEC/GDP effect, % of 2010 CO_2	*Statistical info on incremental FEC/GDP effects, %/a*					Cumulative CO_2/TPES effect, % of 2010 CO_2	Cumulative GDP/POP effect, % of 2010 CO_2	Cumulative POP effect, % of 2010 CO_2
			Md	*Av.*	*Stdev*	*Min*	*Max*		*Md*	*Av.*	*Stdev*	*Min*	*Max*			
Austria	0,7	0,0	-0,7	-0,5	1,1	-1,5	0,6	-2,2	0,0	-1,7	4,3	-6,6	1,5	-3,0	4,2	1,6
Belgium	-4,3	-3,9	-0,9	-1,2	1,1	-2,5	-0,3	-1,1	-3,1	-1,9	5,5	-6,7	4,1	-3,5	1,5	2,7
Bulgaria	-6,9	-4,0	-3,1	-1,6	3,3	-3,8	2,2	-3,2	-1,1	-1,1	4,5	-5,6	3,4	-4,0	6,6	-2,3
Croatia	-17,3	-2,2	-0,7	-0,3	0,9	-1,0	0,8	-4,4	-1,9	-1,9	1,3	-3,3	-0,6	-5,8	-1,1	-3,9
Cyprus	-25,9	-4,4	0,1	-0,6	4,2	-5,1	3,3	-14,7	-3,3	-4,4	2,1	-6,8	-3,2	-1,6	-13,2	8,0
Czech	-7,1	2,0	-0,1	-0,5	1,1	-1,8	0,4	-5,1	-0,1	-1,5	3,4	-5,5	0,9	-6,8	2,6	0,2
Denmark	-17,1	-1,0	0,0	-0,3	2,5	-2,9	2,0	-5,1	-2,9	-3,1	2,5	-5,7	-0,8	-12,7	0,3	1,5
Estonia	22,0	15,6	3,2	2,3	5,8	-3,9	7,6	-10,9	-2,4	-4,0	6,1	-10,8	1,1	1,6	17,1	-1,4
Finland	-6,7	-2,9	-1,0	-1,1	3,0	-4,2	1,8	-0,2	-0,4	-2,0	5,2	-7,8	2,1	-6,5	1,3	1,6
France	-5,2	-0,3	-1,4	-0,3	3,1	-2,6	3,2	-4,2	1,5	-1,6	6,3	-8,9	2,5	-5,2	2,7	1,8
Germany	5,2	-2,1	-0,3	-0,4	0,1	-0,4	-0,3	-3,5	0,3	-1,9	5,4	-8,0	2,1	2,9	7,6	0,3
Greece	-25,6	6,7	-1,0	2,4	6,3	-1,3	9,7	-3,2	-3,8	-1,2	7,4	-6,9	7,1	-4,0	-23,6	-1,4
Hungary	-15,5	-1,4	-0,6	-1,2	3,9	-5,4	2,3	-9,7	-3,9	-3,5	3,2	-6,5	-0,2	-6,9	3,7	-1,2
Ireland	-13,0	1,7	0,3	0,3	1,4	-1,2	1,7	-12,4	-1,4	-4,2	6,3	-11,4	0,2	-4,5	0,9	1,2
Italy	-11,6	-1,9	-0,1	-0,6	1,7	-2,5	0,7	-1,2	-1,9	-1,0	2,6	-3,1	1,9	-6,5	-3,7	1,7
Latvia	-3,1	2,8	-0,1	0,7	1,5	-0,1	2,5	-16,4	-8,1	-6,5	4,8	-10,2	-1,1	-1,9	18,2	-5,8
Lithuania	-4,5	-29,0	-1,1	-1,8	2,4	-4,4	0,1	-6,2	-1,6	-2,7	5,6	-8,8	2,3	17,4	19,5	-6,2
Luxembourg	-2,8	-2,3	-0,9	-0,8	0,9	-1,6	0,1	-6,5	-2,6	-2,6	0,8	-3,4	-1,9	-3,1	-0,1	9,2
Malta	-5,5	-19,3	0,0	-4,4	8,5	-14,2	1,1	3,6	-1,3	-0,8	4,5	-4,9	4,0	0,8	7,0	2,4
Netherlands	-1,0	-3,3	-0,6	-0,9	1,5	-2,5	0,5	1,9	1,7	-1,3	7,0	-9,4	3,7	0,0	-1,1	1,5
Poland	0,3	1,4	1,4	0,8	3,2	-2,6	3,7	-9,3	-3,1	-4,4	2,9	-7,7	-2,5	-3,2	10,5	0,9
Portugal	-17,1	3,8	2,8	2,6	1,1	1,5	3,6	-9,7	-2,5	-2,6	2,1	-4,8	-0,6	-5,9	-4,4	-1,0
Romania	-11,5	-7,3	-3,4	-2,4	2,3	-4,1	0,2	-7,0	-0,3	-2,5	5,3	-8,6	1,3	-2,4	7,2	-2,0
Slovakia	-0,6	2,9	1,4	0,6	2,7	-2,4	2,8	-10,1	-6,7	-3,6	6,8	-8,3	4,3	-3,4	10,2	-0,2
Slovenia	-4,5	-1,6	-0,5	-0,1	1,8	-1,8	1,8	0,8	-0,8	-0,7	1,3	-2,0	0,7	-1,9	-2,7	1,0
Spain	-15,4	2,1	2,2	1,2	4,0	-3,2	4,6	-6,9	-2,7	-2,8	0,3	-3,2	-2,5	-6,7	-4,4	0,5
Sweden	-7,0	6,7	0,8	1,4	1,6	0,1	3,2	-7,7	-3,1	-3,6	3,9	-7,7	0,1	-14,7	5,9	2,9
UK	-2,1	-0,9	0,6	0,1	1,5	-1,6	1,3	-7,1	-1,1	-3,2	6,1	-10,2	1,5	0,2	2,8	2,8
EU-15	*-4,5*	*-0,7*	*-0,2*	*-0,1*	*1,0*	*-1,0*	*1,0*	*-4,1*	*0,0*	*-2,2*	*4,2*	*-7,0*	*0,5*	*-2,8*	*1,8*	*1,4*
EU-28	*-4,4*	*-0,7*	*-0,4*	*-0,1*	*1,1*	*-1,0*	*1,2*	*-4,4*	*-0,3*	*-2,2*	*3,7*	*-6,5*	*0,2*	*-2,7*	*2,4*	*0,9*

In Tables 6-9, the values for the effects of TPES/FEC and FEC/GDP have been marked with different shades of green (decreasing effect), red (increasing effect) or white (relatively close to zero effect). The scales of the shades are based on the following decrease/increase categories:

-20.00% or more	bright green
-19.99%...-10.00%	green
-9.99%...-2.50%	light green
-2.49% – 2.49%	white
2.50%...9.99%	light red
10.00%...19.99%	red
20.00% or more	bright red

In the sense how changes in energy efficiency related indicators TPES/FEC and FEC/GDP have contributed to change in carbon dioxide emissions from fuel combustion (ΔCO2), the performance of EU Member States as well as the performance of the EU as a whole has been very different during the four different time periods, 1990-2000, 2000-2005, 2005-2010 and 2010.2013.

5.1. CO2 decomposition results, EU-28 Member States 1990-2000

In the first analysed time period 1990-2000 (Table 6), CO2 emissions from fuel combustion increased in 12 Member States, and also in the aggregate EU-15 slightly (1.4%). Large increases of CO2 emissions during this 10-year period took place in Cyprus (62.0%), Portugal (52.7%), Spain (37.5%), Ireland (35.6%), and Greece (25.9%). CO2 emissions decreased in 16 Member States and in the EU-28 as a whole (-6.0%), Large decreases took place in Lithuania (-68.3%), Latvia (-63.6%), Estonia (-59.7%), Romania (-48.8%), Bulgaria (-43.4%), Slovakia (-32.7%) and Luxembourg (-25.0%). Like total primary energy supply, also CO2 emissions increased especially in the Mediterranean Member States and decreased in the East European, Baltic and Balkan Member States. In the large EU Member States changes were quite modest during this ten-year period, CO2 emissions from fuel combustion increased in France (5.5%) and Italy (8.0%) but decreased in the UK (-4.8%) and especially in Germany (-13.6%).

In 1990-2000, change in energy intensity (FEC/GDP) had a decreasing effect on CO2 emissions from fuel combustion in 22 Member States, and an increasing effect in six Member States (Table 6), the latter including Portugal, Spain, Cyprus, Croatia, Slovenia, and Belgium. The decreasing effect was relatively large (more than -20%) in 12 Member States: Estonia, Poland, Bulgaria, Ireland, Malta, Slovakia, Romania, Luxembourg, Lithuania, Czech Republic, Denmark and Germany. In Ireland, however, CO2 emissions increased significantly due to a very large increasing effect of economic growth (GDP/POP). Change in energy intensity had a significant decreasing effect also in the EU aggregates, -11.7% in EU-15 and -16.9% in EU-28. Incremental (annual) change in energy intensity had a large variation (large difference in minimum and maximum values and large standard deviation) in many Member States, especially in those with large decrease in CO2 emissions.

The change in efficiency of the energy transformation system (TPES/FEC) had a decreasing effect on CO2 emissions from fuel combustion in 17 Member States in 1990-2000 (Table 6). Large decreasing effects took place in Malta (.19.0%), Luxembourg (-14.2%) and Slovenia (-11.7%). in the other Member States, change in TPES/FEC increased total primary energy supply also in the EU aggregates, 4.3% in EU-15 and only 1.2% in EU-28 due to relatively good performance of the new Member States. When looking at the incremental (annual) effects, Member States such as Malta, Cyprus, Romania and Sweden had large difference in minimum and maximum values and large standard deviation of TPES/FEC during the years 1990-2000 but very different TPES changes (-0.4%, 19.8%, -15.5% and 0.7%, respectively. In this sense the performance of EU Member States was not so "systematic" as in the case of total primary energy supply during the same time period (cf. Table 1 above).

The eight Member States with decreasing effect of both energy efficiency related drivers TPES/FEC and FEC/GDP together with a decrease also in CO2 emissions from fuel combustion, included Denmark, Germany, Latvia, Luxembourg, Malta, Poland, Sweden and the UK. The EU-28 aggregate was also successful in this sense.

5.2. CO2 decomposition results, EU-28 Member States 2000-2005

In the second time period 2000-2005 (Table 7), carbon dioxide emissions from fuel combustion increased in 23 EU Member States and in the EU aggregates (3.5% in both EU-15 and EU-28). Large CO2 emission increases took place during this 5-year period in Luxembourg (42.4%), Malta (27.7%), Austria (21.1%), and Lithuania (20.1%). CO2 emissions decreased in Belgium, Sweden, Denmark, Germany, and Czech Republic with modest percentages varying between -5.9% (Belgium) and -2.4% (Czech Republic). In the large EU Member States France and the UK, CO2 emissions increased 1.5% and 1.9% respectively, and in Germany and Italy the emissions decreased by -3.2% and -0.5%, respectively. When compared to the TPES performance, the overall CO2 performance was slightly better in the light of number of Member States with decreasing CO2 emissions; the number was larger than the number of Member States with decreasing TPES during the same time period. On the other hand, variation between EU Member States was larger in the rate of CO2 change than TPES change, and the increase in CO2 emissions was clearly larger than the increase of TPES in the corresponding Member States.

In the period 2000-2005 (Table 7), change in energy intensity (FEC/GDP) had a decreasing effect on CO2 emissions from fuel combustion in 23 EU Member States, and an increasing effect in five Member States: Luxembourg Austria, Italy, Portugal and Spain within the range from 1.0% (Spain) to 8.9% (Luxembourg). Decreasing effect was over -20% in Slovakia (-22.2%), Romania (-21.2%), Latvia (-20.3%) and Slovakia (-11.2%), large decreasing effects were also in Lithuania (-19.8%), Estonia (-19.4%), Bulgaria (-18.3%), the UK (-16.1%), and Sweden (-15.3%). At the aggregate level, change in energy intensity had a decreasing effect, -4.8% in EU-15 and -4.7% in EU-28. From the large EU Member States France and Germany were close to the EU aggregate values: France -4.9%, and Germany -3.1%. Regarding the incremental (annual) FEC/GDP effects during the years 2000-2005, variation was the largest in Malta. In all those Member States with decreasing CO2 emissions, the energy efficiency related driver FEC/GDP had a contribution.

Change in the efficiency of the energy transformation system (TPES/FEC effect) decreased CO2 emissions from fuel combustion in 13 EU Member States during the period 2000-2005 (Table 7) with quite modest relative shares, the percentage values varying between -7.4% (Ireland) and -0.5% (Italy) of the CO2 emissions in 2000. In addition to these two, decreasing effects took place in Estonia, Cyprus, Hungary, Latvia, Poland, Denmark, Romania, Croatia, Spain, Bulgaria, and Greece. All other Member States had an increasing trend of TPES/FEC on CO2 emissions, the highest relative rates were in Malta (33.1%) and Sweden (10.3%).

Changes in FEC/GDP and TPES/FEC had both a decreasing effect to CO2 emissions in 11 Member states, but only in one of them, Denmark, also CO2 emissions decreased during the time period 2000-2005.

5.3. CO2 decomposition results, EU-28 Member States 2005-2010

In the third time period 2005.2010 (Table 8), CO2 emissions from fuel combustion decreased in 21 EU Member States and decreased in 7 Member States. Large decreases took place in Portugal (-22.5%, Spain (-21.5%) and Romania (-19.3%), while in the others decrease varied between -14.1% and -0.7%. CO2 emissions increased in six Member States (Finland, Estonia, Latvia, Poland, the Netherlands, and Cyprus) and stayed at 2005 level in Slovenia. Increases varied between 3.0% (Cyprus) and 12.7% (Finland). At the EU aggregate level, change in CO2 emissions from fuel combustion was -8.9% in EU-15 and -7.8% in EU-28.

Change in energy intensity (FEC/GDP) had a decreasing effect on CO2 emissions in 24 Member States in 2005-2010 (Table 8). Malta (13.4%), Latvia, the Netherlands, and Denmark had increasing effect. Large decreasing FEC/GDP effects took place in Bulgaria (-27.6%), Romania (-24.4%), Slovakia (-24.3%), and Czech Republic (-17.1%). In the other Member States, the decreasing FEC/GDP effect varied between -14.9% and -0.8%. At the EU aggregate level, energy intensity had a -7.1% decreasing effect on CO2 emissions in EU-15 and -7.2% in EU-28. Malta and Latvia had large variation (large standard deviation and large difference between minimum and maximum values) in incremental (annual) FEC/GDP effects on CO2 emissions from fuel combustion.

Change in efficiency of the energy transformation system (TPES/FEC) had a decreasing effect on CO2 emissions in 16 Member States (Table 8). Malta (-31.6%) and Lithuania (-23.6) had large effects, while in the others, decreasing effect was a small one. Increasing TPES/GDP effects took place in 12 Member States, and they varied between 0.6% and 10.4% (Estonia). In incremental (annual) TPES/FEC effects during this time period, large variation (large standard deviation and large difference in minimum and maximum values) can be observed in Malta and Latvia. The effect of TPES/FEC on CO2 emissions was a decreasing one in both EU aggregates, -1.0% in EU-15 and -1.1% in EU-28.

Altogether 14 Member States had a decreasing effect of FEC/GDP and TPES/FEC on CO2 emissions from fuel combustion in 2005-2010, and in 12 of them, also CO2 emissions decreased. These Member States included Austria, Belgium, Croatia, Germany, Greece, Italy, Lithuania, Luxembourg, Portugal, Slovakia, Sweden, and the UK.

5.4. CO2 decomposition results, EU-28 Member States 2010-2013

In the most recent time period 2010-2013 (Table 9), CO2 emissions from fuel combustion decreased in 25 EU Member States. A large increase took place during this short 3-year period in Estonia (22.0%), and marginal increases in Austria and Poland. Cyprus (-25.9%), Greece (-25.6%), Croatia (-17.3%), Denmark (-17.1%), Portugal (-17.1%), Hungary (-15.5%), and Spain (-15.4%) had large decreases. In Ireland (-13.0%), Italy (-11.6%), and Romania (-11.5%) CO2 decrease was over -10% during this period. In the other Member States the CO2 emissions decreased in a range between -7.1% and -0.6%. In the aggregate level, decrease in CO2 emissions from fuel combustion was -4.5% in EU-15 and -4.4% in EU-28.

Change in energy intensity (FEC/GDP) decreased CO2 emissions from fuel combustion in almost all EU Member States (Table 9), only Malta, Netherlands and in Slovenia had a slight increasing FEC/GDP effect. The most significant contributions to the CO2 emissions by this effect were in Latvia (-16.4%), Cyprus (-14.7%), Ireland (-12.4%), Estonia (-10.9%) and Slovakia (-10.1%). In the other Member States the decreasing effect varied in a range from -9.7% to -0.2%. The EU aggregate values were 4.1% for EU-15 and -4-4% for EU-28.

Change in the efficiency of the energy transformation system (TPES/FEC) had a decreasing effect on CO2 emissions in 18 EU Member States (Table 9). Large decreasing effects were in Lithuania (-29.0%) and Malta (-19.3%), in the other Member States the effects varied between -7.3% and -0.3%. Increasing effects in 10 Member States varied between 1.4% and 15.6% (Estonia). EU-15 and EU-28 had both a TPES/FEC effect value -0.7%. Variation in the incremental (annual) values of the TPES/FEC effect were large in Greece, Netherlands, and Slovakia.

In 14 EU Member States both energy efficiency related drivers FEC/GDP and TPES/FEC had a decreasing effect on CO2 emissions from fuel combustion, and in all 14 of them also the CO2 emissions decreased during the time period 2010-2013. These Belgium, Bulgaria, Croatia, Cyprus, Denmark, Finland, France, Germany, Hungary, Italy, Lithuania, Luxembourg, Romania, and the UK.

6. Performance of EU-28 Member States in energy efficiency

The analyses in Chapters 3, 4 and 5 show that the performance of EU-28 Member States in terms of trends of energy efficiency indicators, and the effects of these indicators as drivers of change of total primary energy supply and carbon dioxide emissions from fuel combustion, have changed over time. The analyses covered four different time periods, 1990-2000, 2000-2005, 2005-2010 and 2010-2013. This Chapter sums up how the EU Member States have performed in energy efficiency according to the TPES and CO2 decomposition results presented above in Tables 2-5 (TPES) and 6-9 (CO2).

Summary Tables 11 (for TPES) and 12 (for CO2) show the performance of each EU Member State regarding the above mentioned options. A Member State gets a point in Table 11 and Table 12 for every time period during which (i) TPES or CO2 has decreased (ΔTPES<0 or ΔCO2<0), FEC/GDP has a decreasing effect on TPES or CO2, or (iii) TPES/FEC has a decreasing effect on TPES or CO2. TPES. Thus, during four different time periods the maximum number of points for one Member State (or EU aggregate) is 4x3=12 in both Tables 11 and 12. The number of points each Member State has gained is included in the first column of Table 11 and Table 12.

The number of points in Table 11 and Table 12 is quite a loose criteria for a good energy efficiency performance. Regarding the energy and climate policy targets related to energy efficiency, the effect of energy efficiency on total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion (CO2) needs to be assessed as well. Thus, a tighter criteria takes into account also this and rewards if improving energy efficiency also helps in reaching the policy targets during a same time period. For simplicity, this requirement is operationalized in a way that a decreasing effect of both energy efficiency related drivers FEC/GDP and TPES/FEC together with a decreasing TPES, or together with a decreasing CO2, gives an additional point for a Member State during each time period. The maximum number of these additional points is four (4) points, and each time period which fulfills this criterion is highlighted with a green color in both Tables 11 and 12.

Table 11. Summary of the energy efficiency performance of EU-28 Member States in decomposition analysis of total primary energy supply (TPES), 1990-2013. In the table, FEC/GDP and TPES/FEC refer to the decreasing effect of these drivers on TPES.

EU Member State	Points	1990-2000			2000-2005			2005-2010			2010-2013		
		ΔTPES<0	FEC/GDP	TPES/FEC	ΔTPES<0	FEC/GDP	TPES/FEC	ΔTPES<0	FEC/GDP	TPES/FEC	ΔTPES<0	FEC/GDP	TPES/FEC
Austria	7		x	x					x	x	x	x	x
Belgium	7			x		x			x	x	x	x	x
Bulgaria	9	x	x			x	x	x	x		x	x	x
Croatia	10	x		x		x	x	x	x	x	x	x	x
Cyprus	7			x		x	x		x		x	x	x
Czech R.	8	x		x		x		x	x		x	x	x
Denmark	7		x	x		x	x				x	x	x
Estonia	6	x		x		x	x		x			x	
Finland	7		x	x		x			x		x	x	x
France	8		x	x		x		x	x		x	x	x
Germany	10	x	x	x		x		x	x	x	x	x	x
Greece	9		x	x		x	x	x	x	x	x	x	
Hungary	9	x		x		x	x	x	x		x	x	x
Ireland	8		x	x		x	x	x	x		x	x	
Italy	8		x				x	x	x	x	x	x	x
Latvia	9	x	x	x		x	x	x		x	x	x	
Lithuania	9	x	x			x		x	x	x	x	x	x
Luxembourg	9	x	x	x				x	x	x	x	x	x
Malta	9	x	x	x		x		x		x	x	x	x
Netherlands	7		x	x		x				x	x	x	x
Poland	10	x	x	x		x	x		x	x	x	x	x
Portugal	5							x	x	x	x	x	
Romania	9	x	x			x	x	x	x		x	x	x
Slovakia	8	x	x			x		x	x	x	x	x	
Slovenia	8			x		x		x	x	x	x	x	x
Spain	7		x				x	x	x	x	x	x	
Sweden	8		x	x		x		x	x	x	x	x	
UK	9		x	x	x	x		x	x	x	x	x	
EU-15	8		x			x		x	x	x	x	x	x
EU-28	8		x			x		x	x	x	x	x	x

Table 12. Summary of the energy efficiency performance of EU-28 Member States in decomposition analysis of carbon dioxide emissions from fuel combustion (CO2), 1990-2013. In the table, FEC/GDP and TPES/FEC refer to the decreasing effect of these drivers on CO2 emissions.

EU Member State	Points	1990-2000			2000-2005			2005-2010			2010-2013		
		ΔCO2<0	FEC/GDP	TPES/FEC	ΔCO2<0	FEC/GDP	TPES/FEC	ΔCO2<0	FEC/GDP	TPES/FEC	ΔCO2<0	FEC/GDP	TPES/FEC
Austria	6		x	x				x	x	x		x	
Belgium	9			x	x	x		x	x	x	x	x	x
Bulgaria	9	x	x			x	x	x	x		x	x	x
Croatia	10	x		x		x	x	x	x	x	x	x	x
Cyprus	7			x		x	x		x		x	x	x
Czech R.	8	x	x		x	x		x	x		x	x	
Denmark	10	x	x	x	x	x	x	x			x	x	x
Estonia	6	x	x			x	x		x			x	
Finland	6		x			x			x		x	x	x
France	8		x	x		x		x	x		x	x	x
Germany	11	x	x	x	x	x		x	x	x	x	x	x
Greece	9		x	x		x	x	x	x	x	x	x	
Hungary	9	x	x			x	x	x	x		x	x	x
Ireland	8		x	x		x	x	x	x		x	x	
Italy	8		x				x	x	x	x	x	x	x
Latvia	8	x	x	x		x	x			x	x	x	
Lithuania	9	x	x			x		x	x	x	x	x	x
Luxembourg	9	x	x	x				x	x	x	x	x	x
Malta	8	x	x	x		x		x		x	x		x
Netherlands	6		x	x		x				x	x		x
Poland	8	x	x	x		x	x		x	x		x	
Portugal	5							x	x	x	x	x	
Romania	9	x	x			x	x	x	x		x	x	x
Slovakia	8	x	x			x		x	x	x	x	x	
Slovenia	6			x		x			x	x	x		x
Spain	6			x			x	x	x		x	x	
Sweden	10	x	x	x	x	x		x	x	x	x	x	
UK	10	x	x	x		x		x	x	x	x	x	x
EU-15	9		x	x		x		x	x	x	x	x	x
EU-28	10	x	x	x		x		x	x	x	x	x	x

Finally, Table 13 wraps up the results from Tables 11 and 12 for ranking the EU Member States. The ranking is sensitive to choices made even within this analysis (which time period(s), TPES or CO2, or both, FEC/GDP or TPES/FEC or both, requirement of simultaneously, possible weighting, etc.), so there is no reason to draw strong conclusions – here the focus has been on simple decomposition results, and the effects of other possible drivers have not been taken into account and by no means analysed. However, Table 13 gives the reader some choice of freedom to look at how different EU Member States have performed in the light of this analysis, and give weight either to total primary energy supply or CO2 emissions, or the driving forces, i.e. energy intensity (FEC/GDP) and efficiency of the energy transformation system (TPES/FEC). It is also possible to go back to Tables 11 and 12 and look what happens if some time periods are left out. It is also possible to go back to the incremental decomposition results and choose different time periods, or even calculate the points on annual basis for a selected time period.

Table 13. Wrap-up and ranking of the energy efficiency performance of EU-28 Member States, 1990-2013.

EU Member State	TPES points			CO2 points			Total
	from Table 11	Additional	TPES subtotal	from Table 12	Additional	CO2 subtotal	
Austria	7	1	8	6	1	7	15
Belgium	7	1	8	9	2	11	19
Bulgaria	9	1	10	9	1	10	20
Croatia	10	2	12	10	2	12	24
Cyprus	7	1	8	7	1	8	16
Czech R.	8	1	9	8	0	8	17
Denmark	7	1	8	10	3	13	21
Estonia	6	0	6	6	0	6	12
Finland	7	1	8	6	1	7	15
France	8	1	9	8	1	9	18
Germany	10	3	13	11	3	14	27
Greece	9	1	10	9	1	10	20
Hungary	9	1	10	9	1	10	20
Ireland	8	0	8	8	0	8	16
Italy	8	2	10	8	2	10	20
Latvia	9	1	10	8	1	9	19
Lithuania	9	2	11	9	2	11	22
Luxembourg	9	3	12	9	3	12	24
Malta	9	2	11	8	1	9	20
Netherlands	7	1	8	6	0	6	14
Poland	10	2	12	8	1	9	21
Portugal	5	1	6	5	1	6	12
Romania	9	1	10	9	1	10	20
Slovakia	8	1	9	8	1	9	18
Slovenia	8	2	10	6	0	6	16
Spain	7	1	8	6	0	6	14
Sweden	8	1	9	10	2	12	21
UK	9	3	12	10	3	13	25
EU-15	8	2	10	9	2	11	21
EU-28	8	2	10	10	3	13	23

7. Conclusions

In the first deliverable of the EUFORIE project WP2, energy efficiency of EU-28 Member States has been studied. Focus has been on macro level indicators of energy efficiency, their long-term historical trends and their decomposed effects on energy consumption (total primary energy supply TPES) and energy-related greenhouse gas emissions (carbon dioxide emissions from fuel combustion). In the empirical analyses, the most recent data from the International Energy Agency (IEA 2015) has been used.

The indicators of energy efficiency used in this study are energy intensity of the economy (final energy consumption FEC divided by gross domestic product GDP in fixed USD 2005 prices) and efficiency of the energy transformation system, ratio of total primary energy supply TPES and final energy consumption FEC). The long-term trends of these indicators can be heavily generalized by saying that energy intensity has decreased significantly in most of the EU-28 Member States, but the trend of TPES/FEC ratio is not so clear and varies a lot between different Member States. Increasing use of electricity affects the TPES/FEC ratio very differently, depending on the used primary energy sources (fossil, nuclear, renewables) and modes of electricity production (CHP, condensing power). Essential here is, how primary energy is calculated in energy statistics. In some cases such as hydro, wind, and solar, produced electricity is calculated as such also in primary energy, in some other cases such as nuclear or geothermal, a thermal efficiency is assumed. This may make the use of aggregated energy indicators and their international comparison problematic. Thus, the EU Member States relying on nuclear power and fossil fuels may have a stronger increasing trend in the TPES/FEC ratio than Member States relying on energy sources where the statistical ratio equals to 1. On the other hand, calculation principles are similar for all EU Member States, so it is possible to make comparisons being aware of the statistical calculation procedures.

The effect of energy intensity on total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion were studied by chained two-factor decomposition analysis based on the Advanced Sustainability Approach (ASA) developed by the Finland Futures Research Centre at Turku School of Economics, University of Turku. The analysis was made for the period 1990-2013 using incremental (annual) changes for the first time, and the results were presented as incremental sums for four time periods, the first one was ten years (1990-2000), then two five-year periods (2000-2005, 2005-2010) and the most recent three-year period (2010-2013). Based on the results, the EU Member States were also ranked based on their performance in energy efficiency, based on whether total primary energy supply and carbon dioxide emissions from fuel combustion decreased or not, and whether the energy efficiency related drivers FEC/GDP and TPES/FEC had a decreasing effect on TPES and CO2 or not. The performance of EU Member States was ranked by giving points for a good performance (decrease in TPES or/and CO2, and each a decreasing effect of the energy efficiency related drivers during different time periods. Additional point were given for each time period, during which both drivers FEC/GDP and TPES/FEC had a decreasing effect, and also a decrease in the corresponding indicator, TPES of CO2, took place simultaneously.

A ranking based on the gained points was made, and the sensitivity of the results depending on different choices was recognized (which is always the case in rankings). There are, however, quite significant differences between EU Member States' performance in energy efficiency, and this study brings something out of them. In the applied ranking, overall good performance was shown by a few EU Member States such as Germany and the UK, and their good performance was also reflected in the relatively good-looking performance of the EU-28 and EU-15 aggregates.

Some general observations are worth mentioning from the analyses carried out in this report:

There is significant variation between the annual changes among the EU Member States, both in the absolute trends of energy efficiency drivers FEC/GDP and TPES/FEC, as well as in the decomposed effects of these drivers on total primary energy supply and carbon dioxide emissions from fuel combustion. The variation is large especially in small EU Member States and the new EU Member States.

The energy efficiency performance of the EU Member States seems to improve over time. Time period 2000-2005 was the worst period in practically all Member States, but since then both total primary energy supply and CO_2 emissions from fuel combustion have decreased in many Member States, but not in all of them.

The trend of energy intensity is good in general terms, but in practice it depends not only on good performance in energy efficiency, but also on poor economic performance which is directly reflected into the indicator FEC/GDP.

The trend of TPES/FEC ratio reflects the efficiency of the energy transformation system from primary energy to final energy consumption. In some countries there is a decreasing trend, but also increasing trends have been identified. This may partly be due to changes in real efficiency, but is also influenced by the fact that energy statistics do not treat different energy sources used in electricity production in a similar way. Some energy sources such as hydro, wind and solar have a TPES/FEC ratio of 1, but nuclear has a ratio 3, and geothermal even higher ratio 10. Fuel-based electricity generation is more coherent in this sense, when primary energy is calculated from the fuel's energy content, and electricity and heat are treated as such in final energy consumption. However, the TPES/FEC ratio does not take into account the efficiency of the appliances consuming the final energy and providing the actual energy service.

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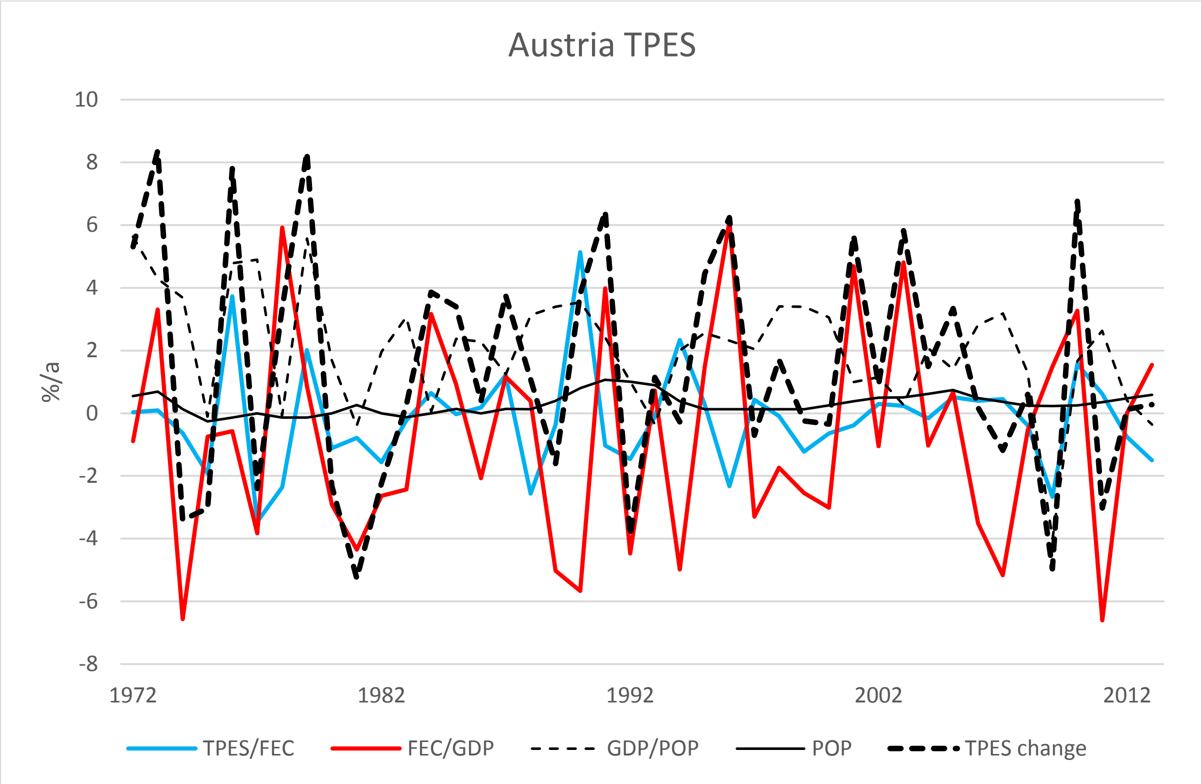
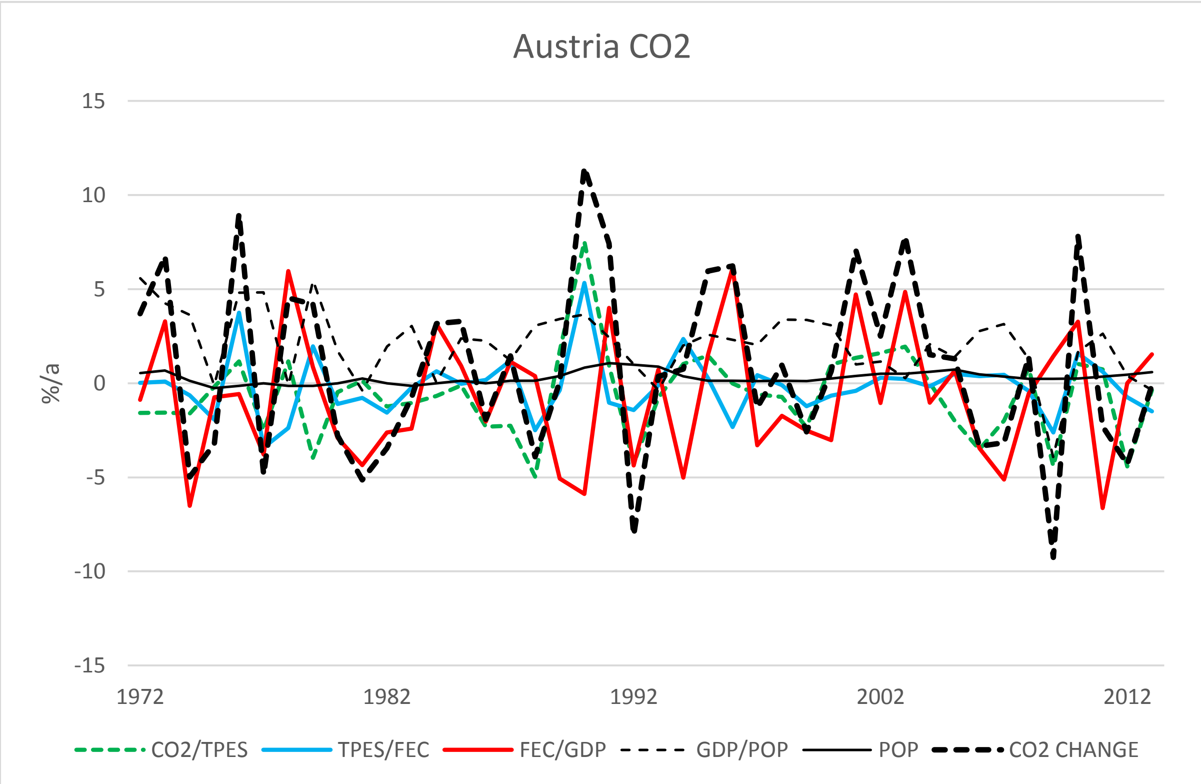
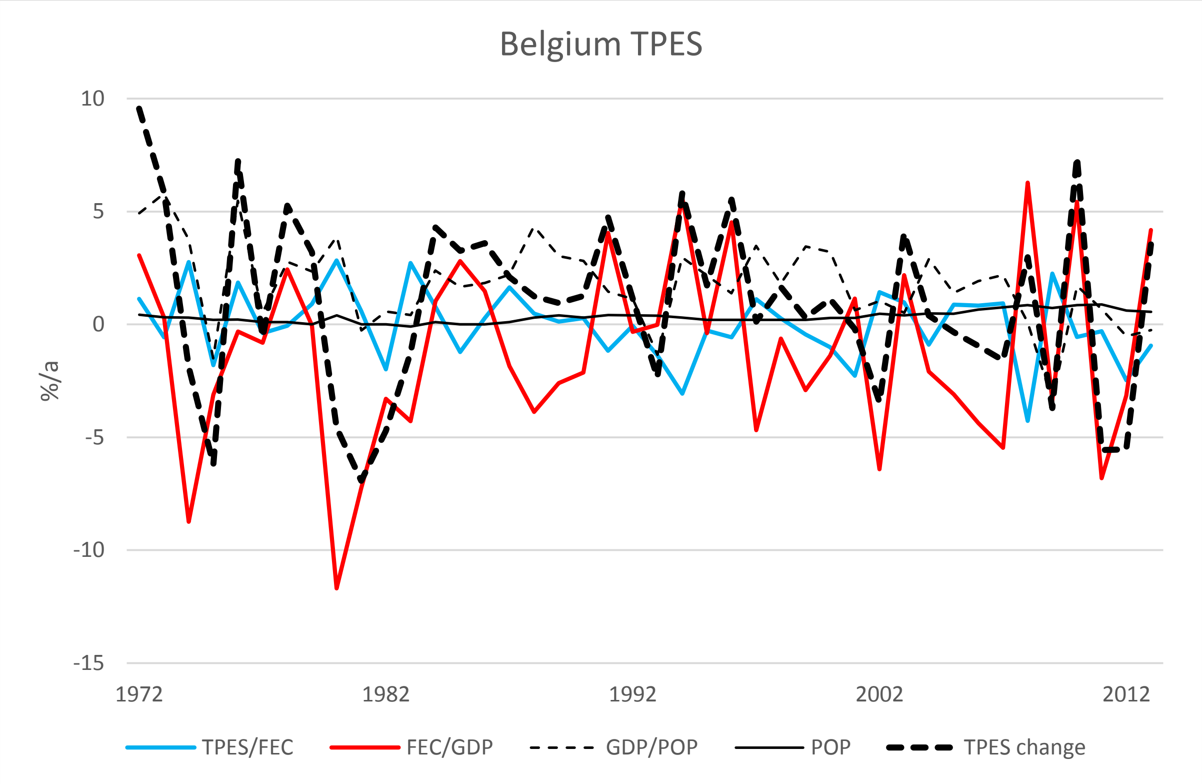
Appendix 1.

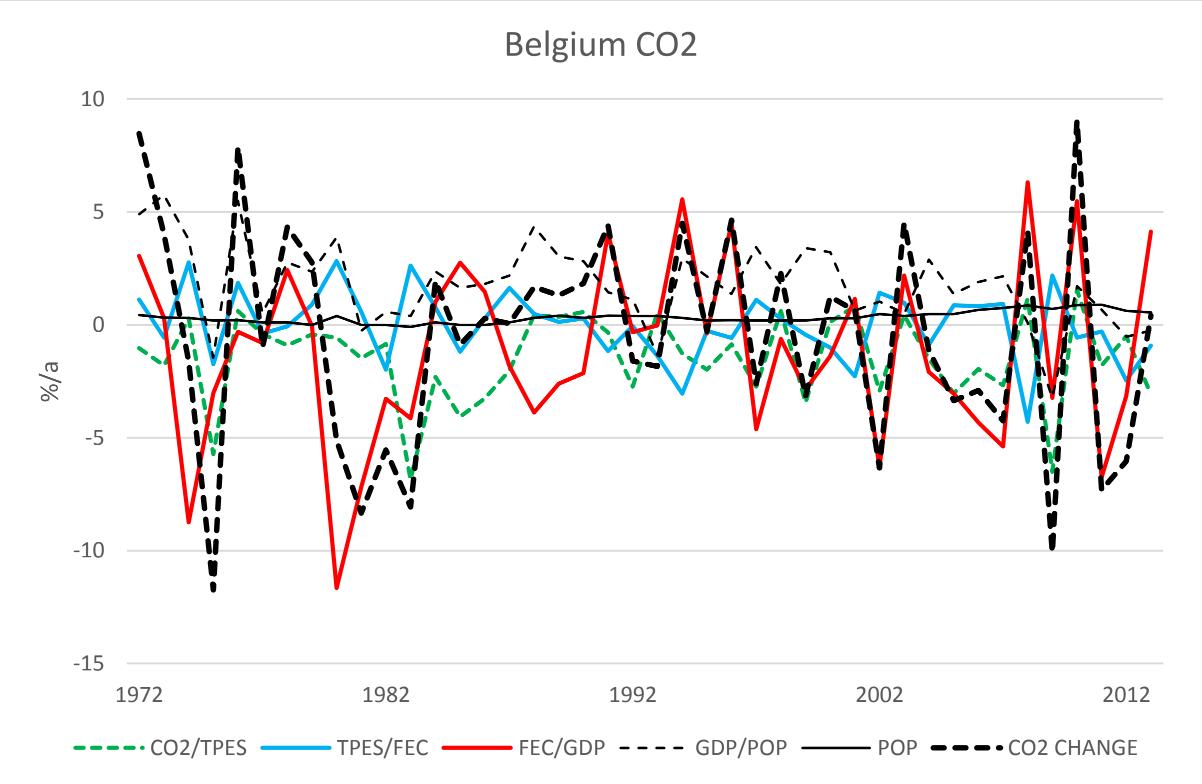
Figures of incremental decomposition results of total primary energy supply (TPES) and carbon dioxide emissions CO2 for EU Member States and EU-15 and EU-28 aggregates, 1990-2013.


Austria TPES
10
8
6
4
2
0
-2
-4
-6
-8
%/a
1972
1982
1992
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change

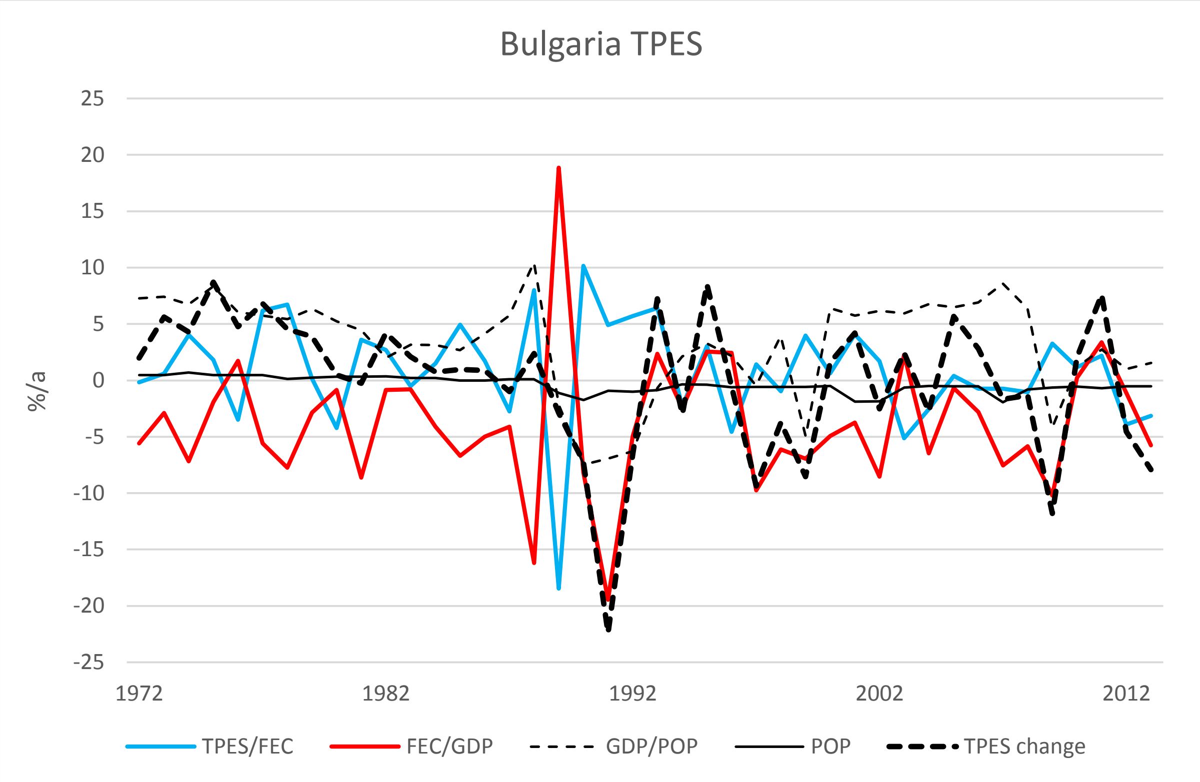

Austria CO2
15
10
5
0
-5
-10
-15
%/a
1972
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE

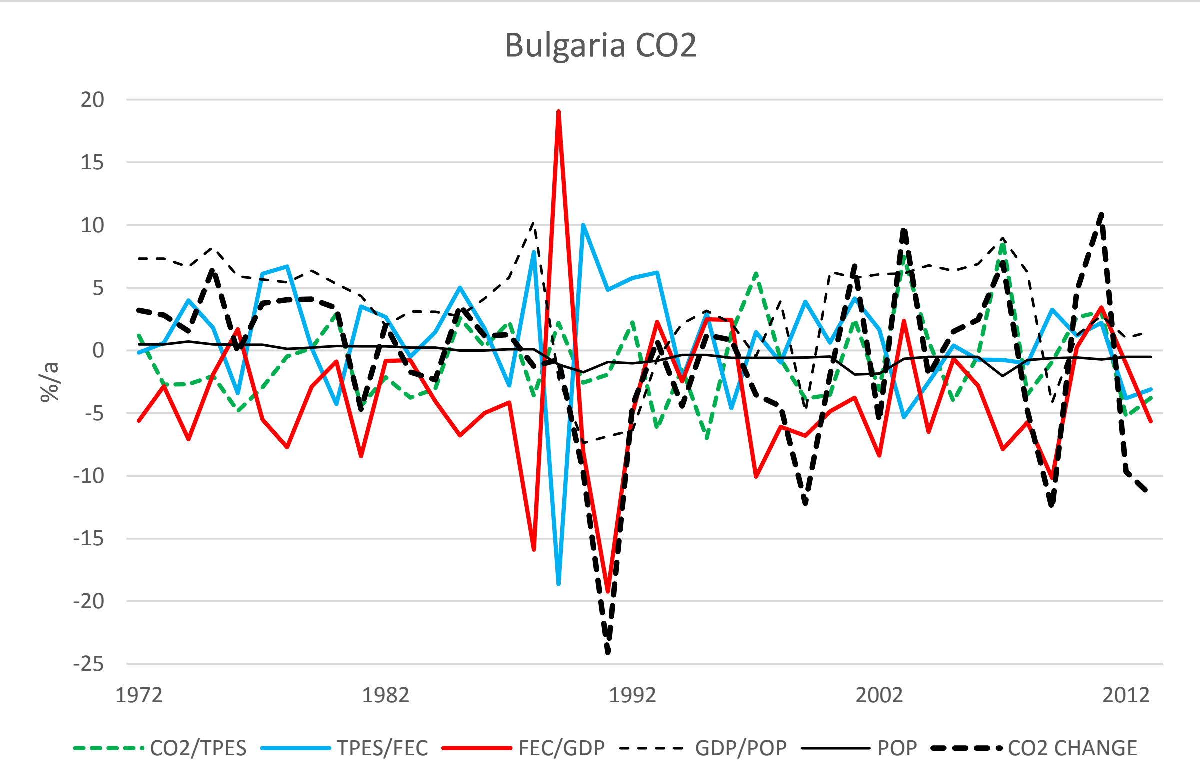


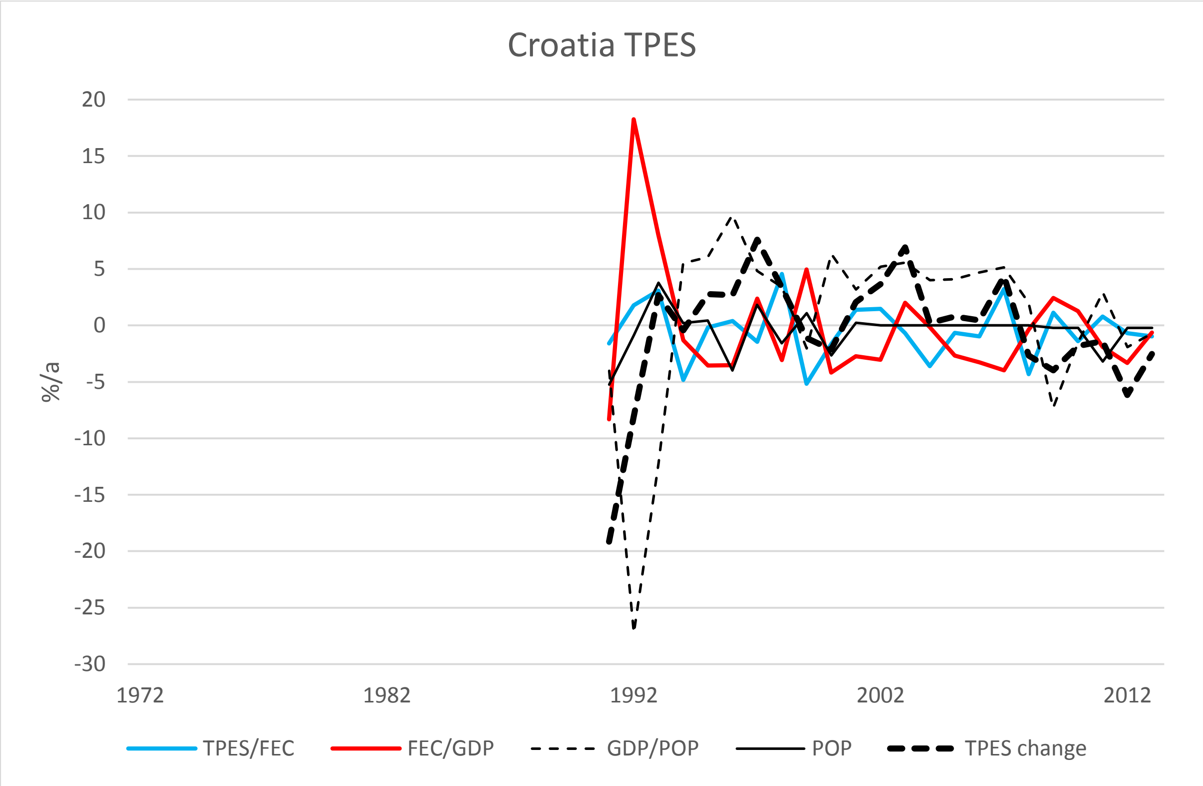
Belgium TPES
10
5
0
-5
-10
-15
%/a
1972
1982
1992
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change

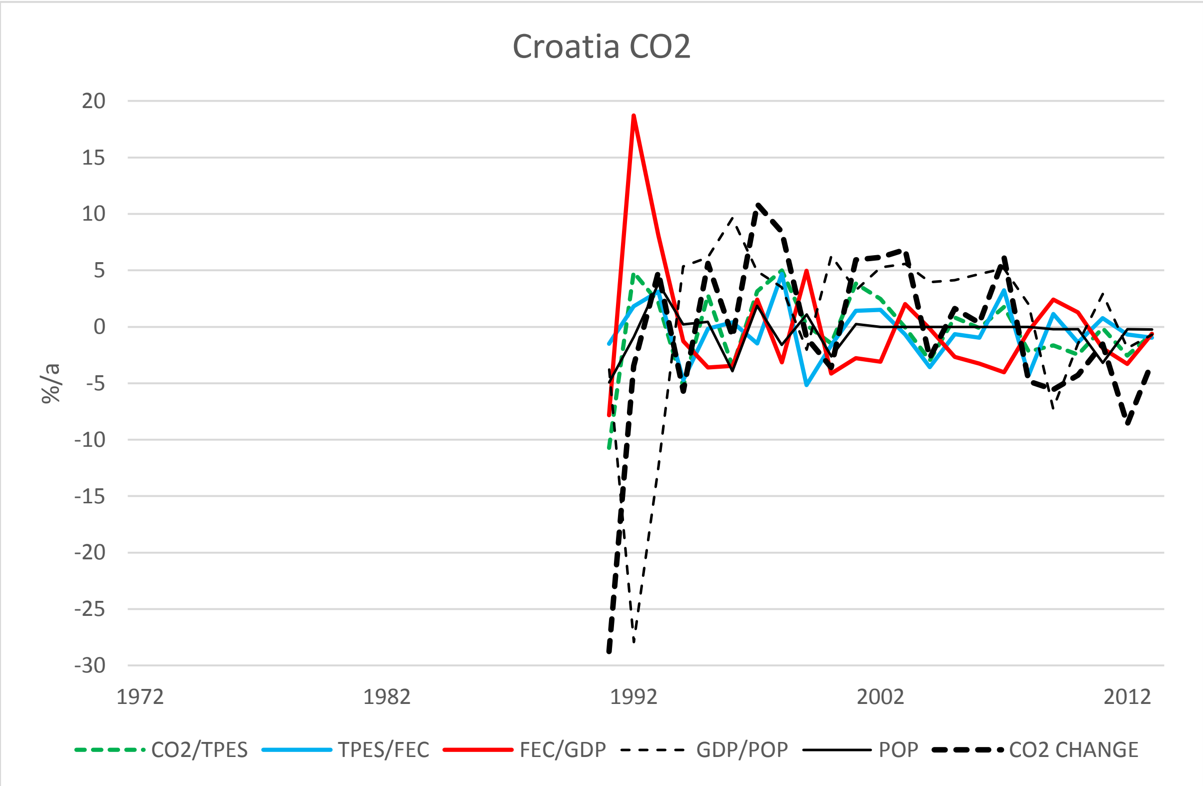


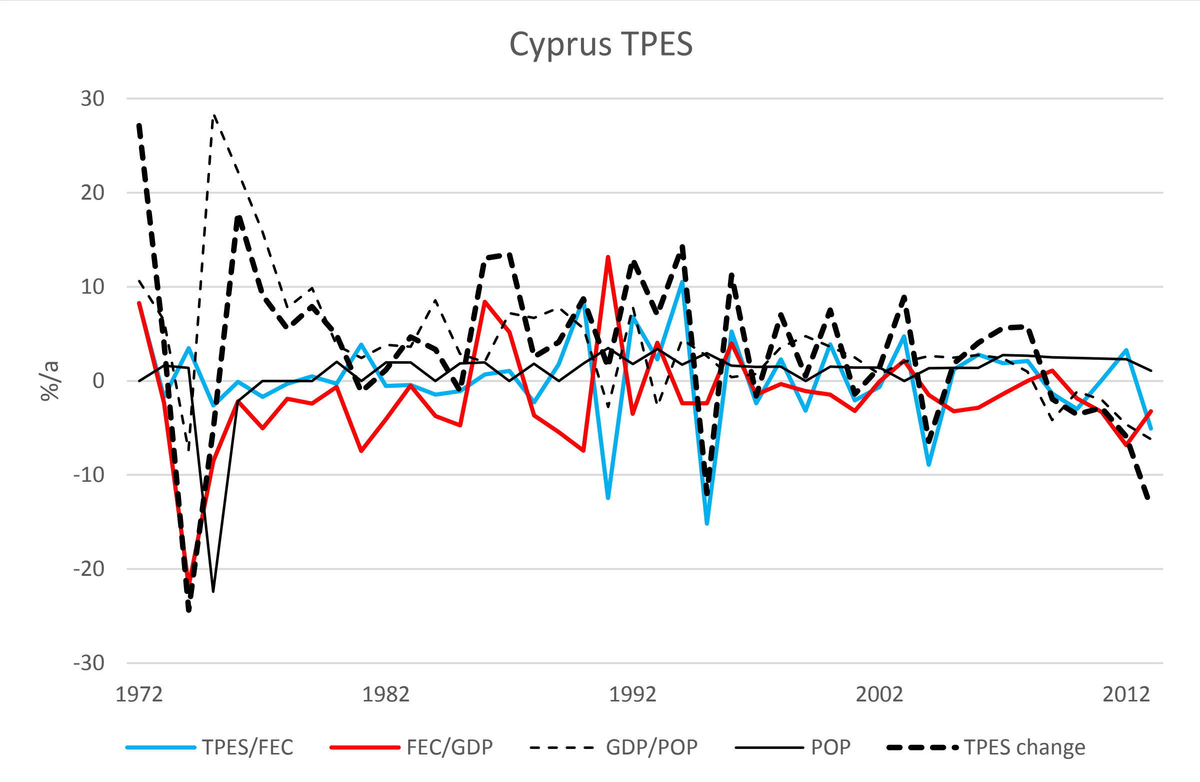
Belgium CO2
10
5
0
-5
-10
-15
%/a
1972
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE

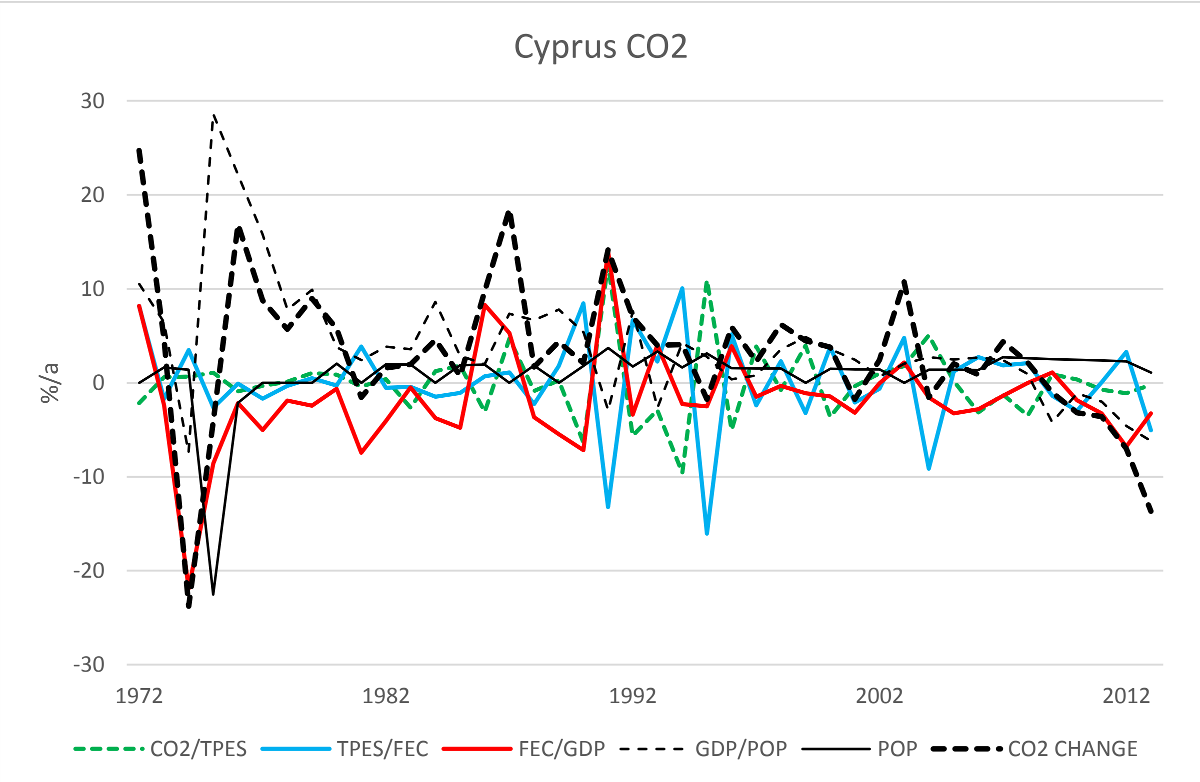

Bulgaria TPES
25
20
15
10
5
0
-5
-10
-15
-20
-25
%/a
1972
1982
1992
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change

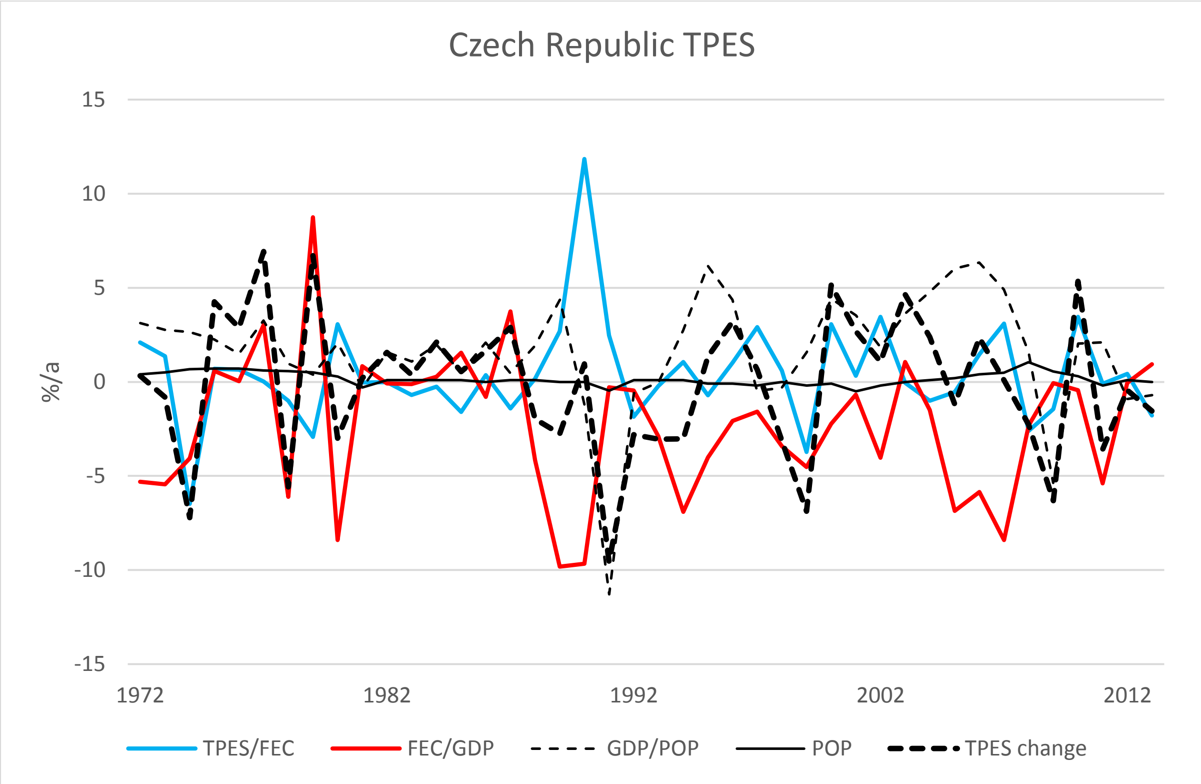

Bulgaria CO2
20
15
10
5
0
-5
-10
-15
-20
-25
%/a
1972
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE


Croatia TPES
20
15
10
5
0
-5
-10
-15
-20
-25
-30
%/a
1972
1982
1992
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change


Croatia CO2
20
15
10
5
0
-5
-10
-15
-20
-25
-30
%/a
1972
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE


Cyprus TPES
30
20
10
0
-10
-20
-30
%/a
1972
1982
1992
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change


Cyprus CO2
30
20
10
0
-10
-20
-30
%/a
1972
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE


Czech Republic TPES
15
10
5
0
-5
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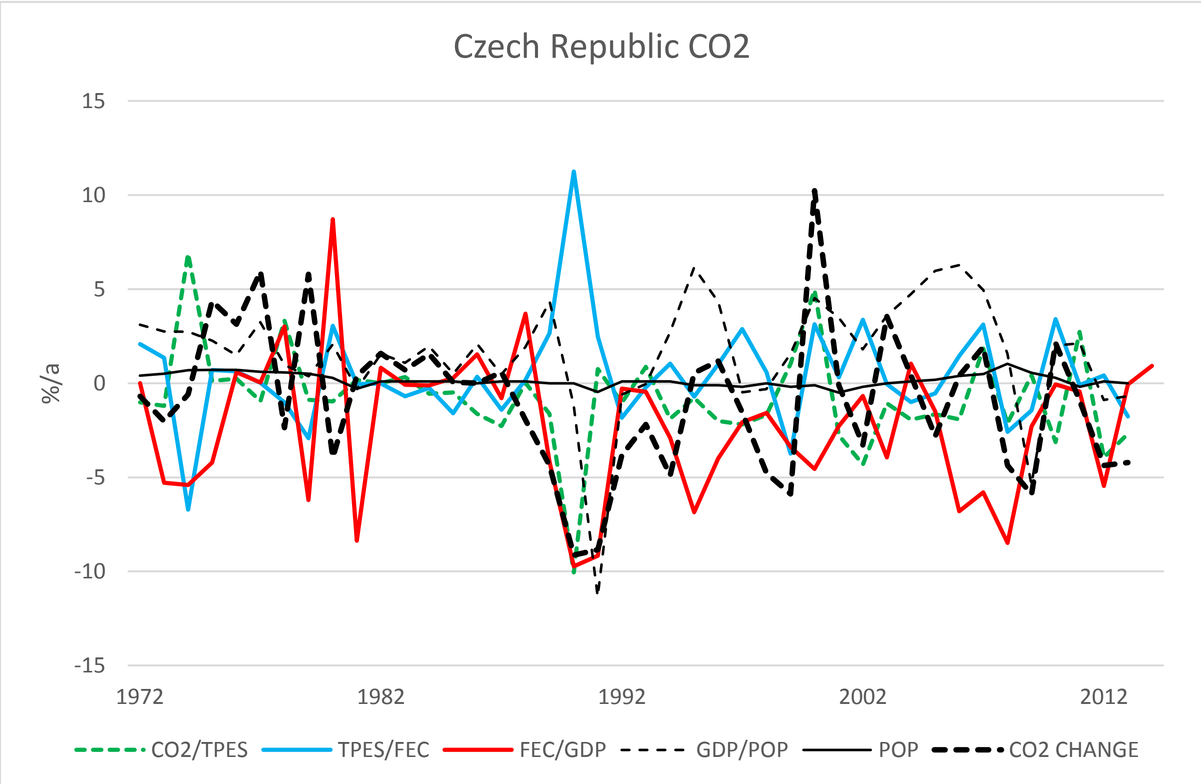
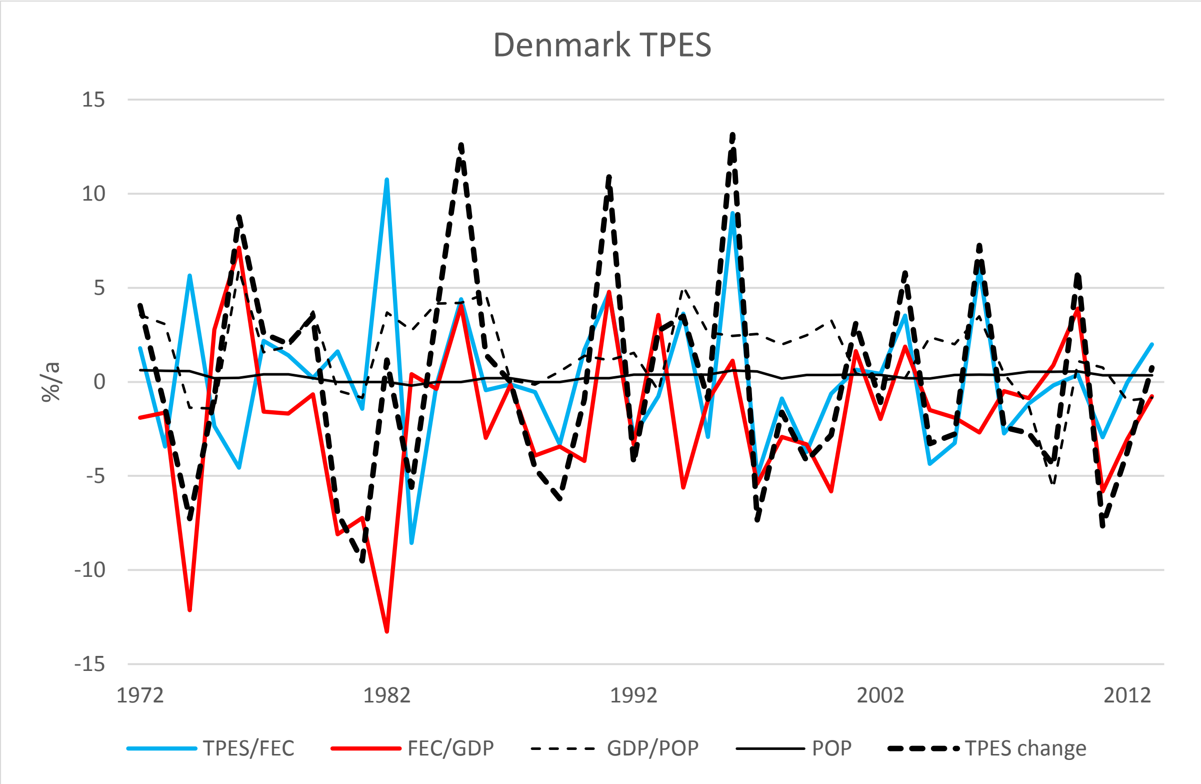
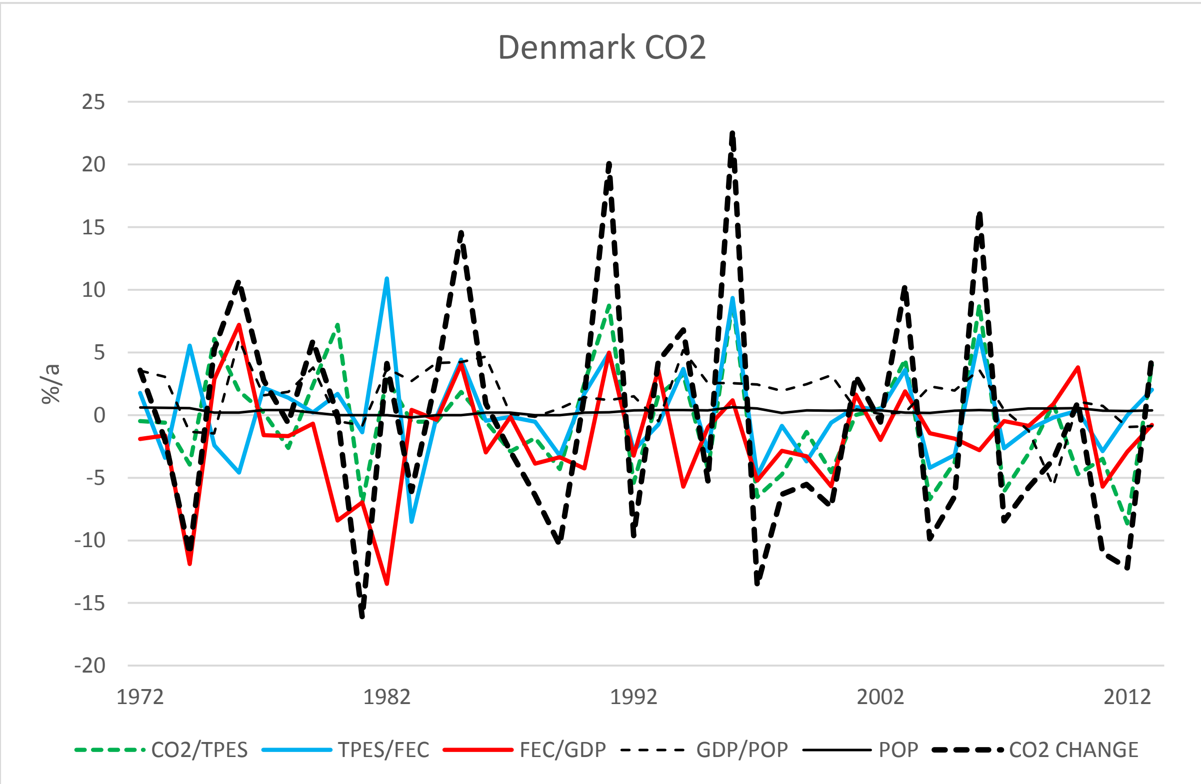
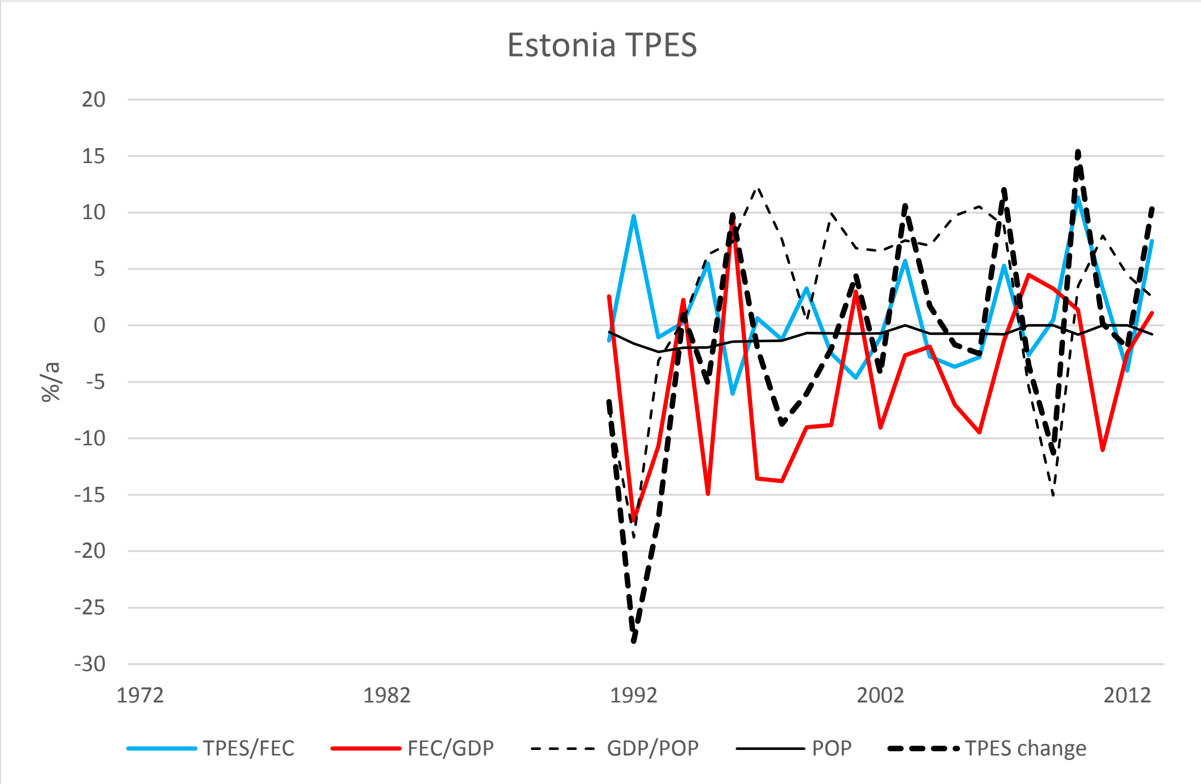
-15
%/a
1972
1982
1992
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change


Czech Republic CO2
15
10
5
0
-5
-10
-15
%/a
1972
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE


Denmark TPES
15
10
5
0
-5
-10
-15
%/a
1972
1982
1992
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change


Denmark CO2
25
20
15
10
5
0
-5
-10
-15
-20
%/a
1972
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE


Estonia TPES
20
15
10
5
0
-5
-10
-15
-20
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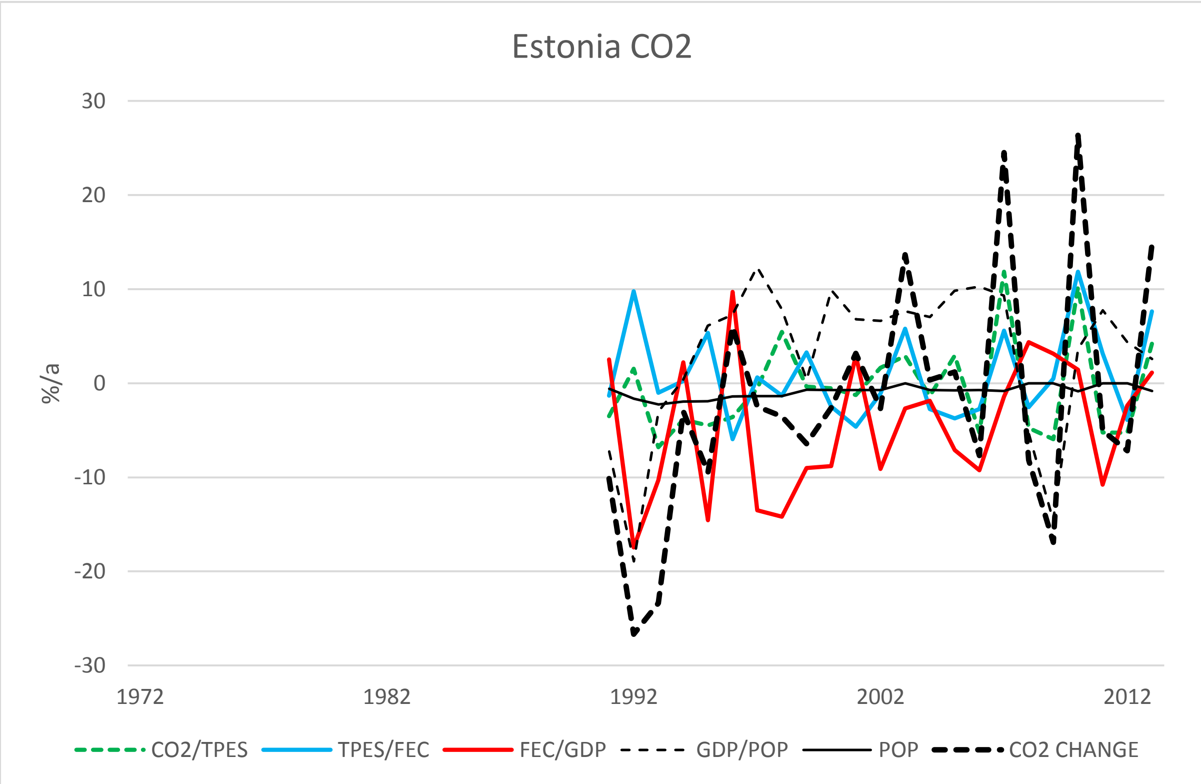
TPES change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2012
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FEC/GDP
GDP/POP
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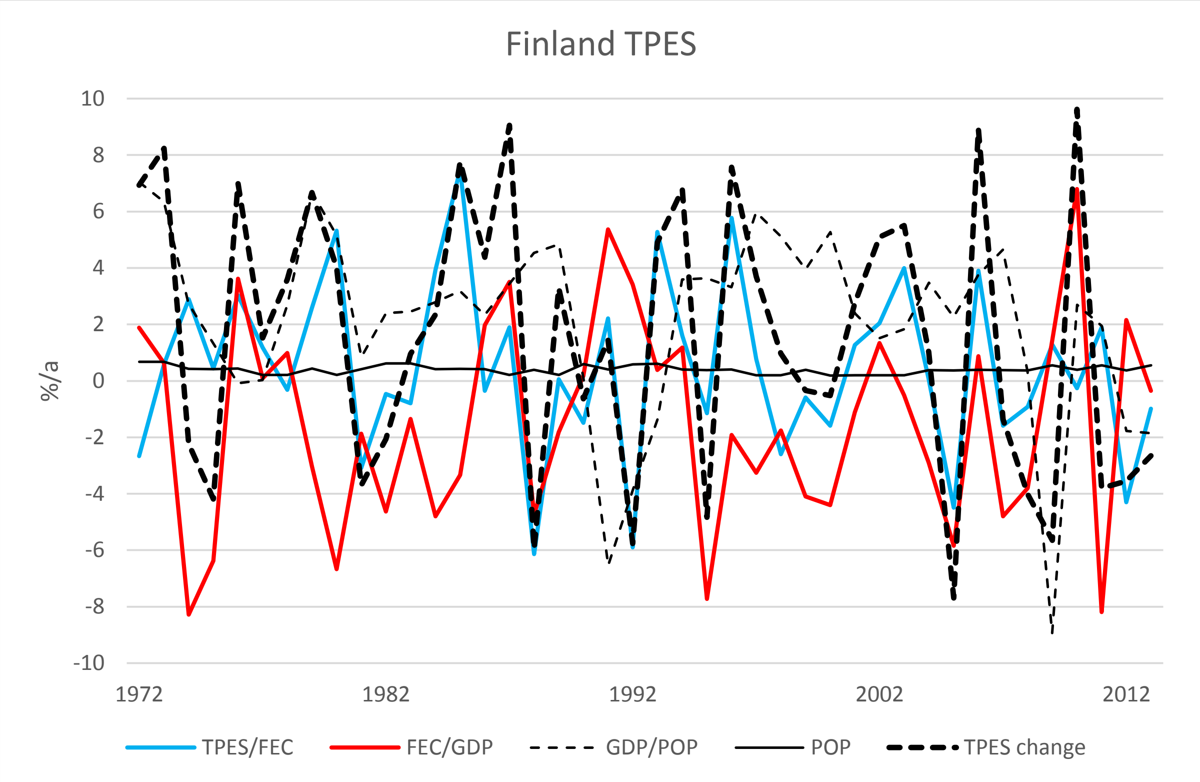
CO2 CHANGE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FEC/GDP
GDP/POP
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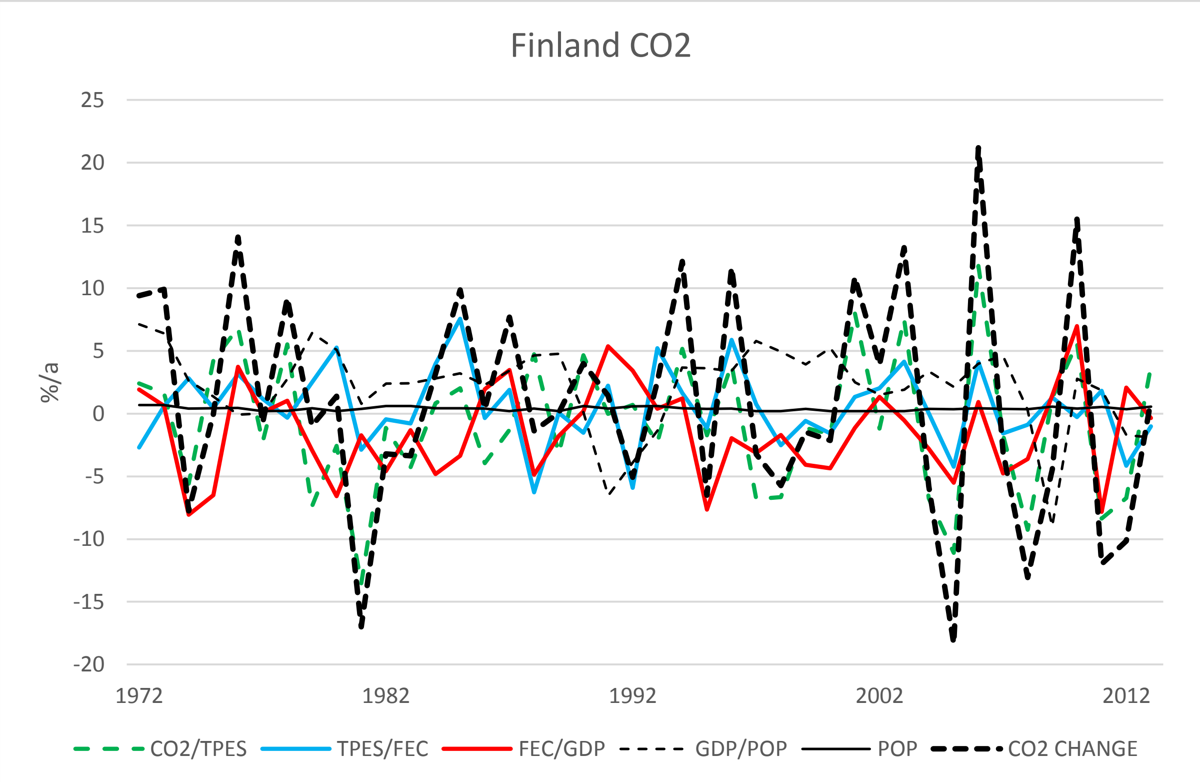
TPES change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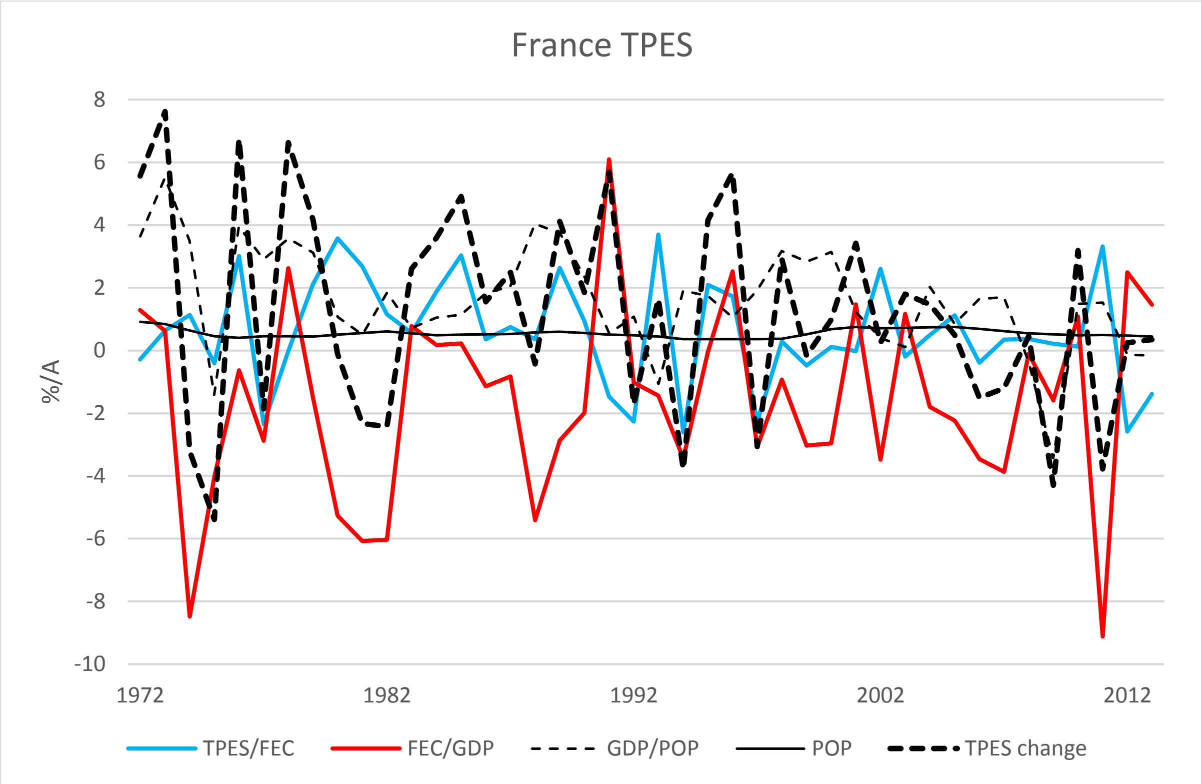
FEC/GDP
GDP/POP
POP
CO2 CHANGE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GDP/POP
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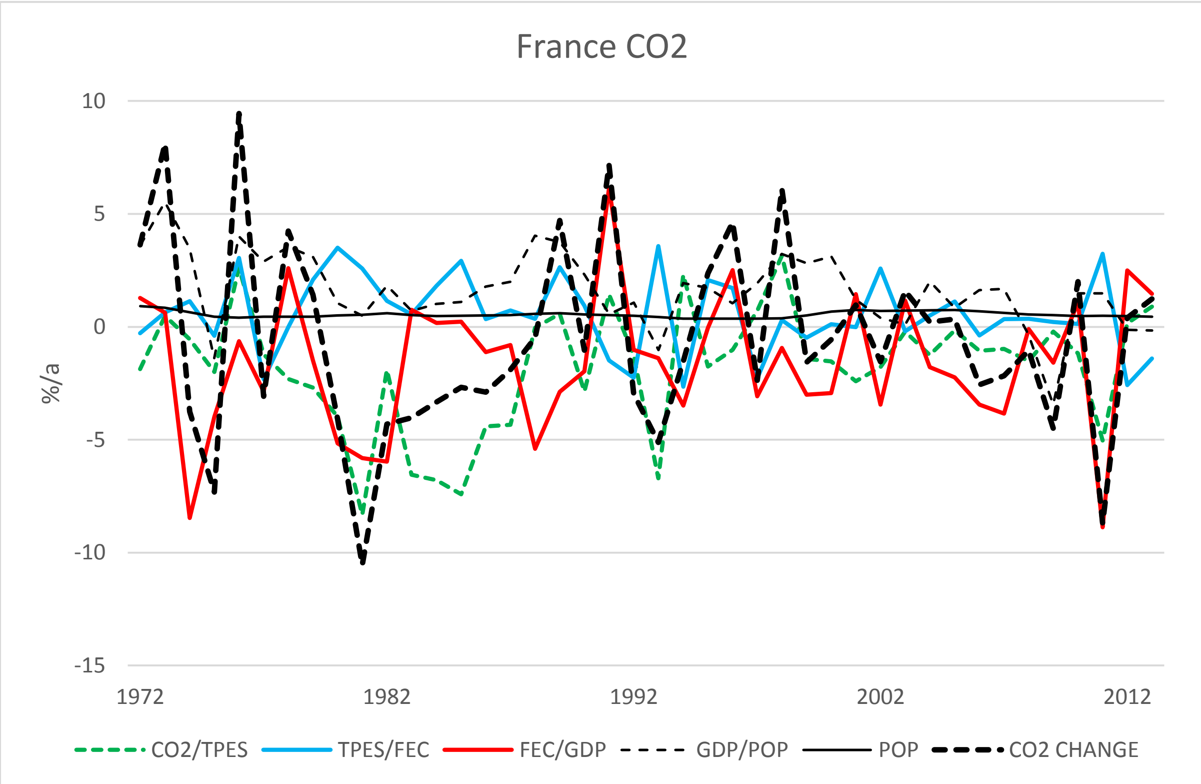
TPES change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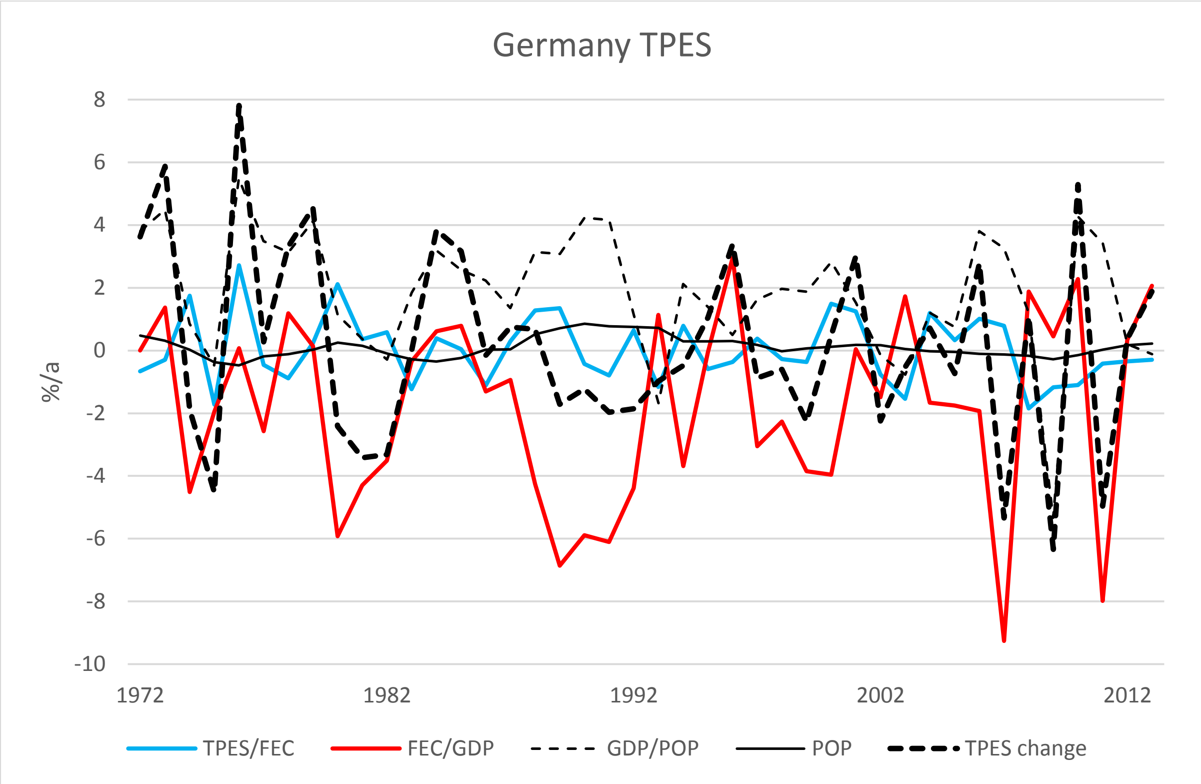
FEC/GDP
GDP/POP
POP
CO2 CHANGE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GDP/POP
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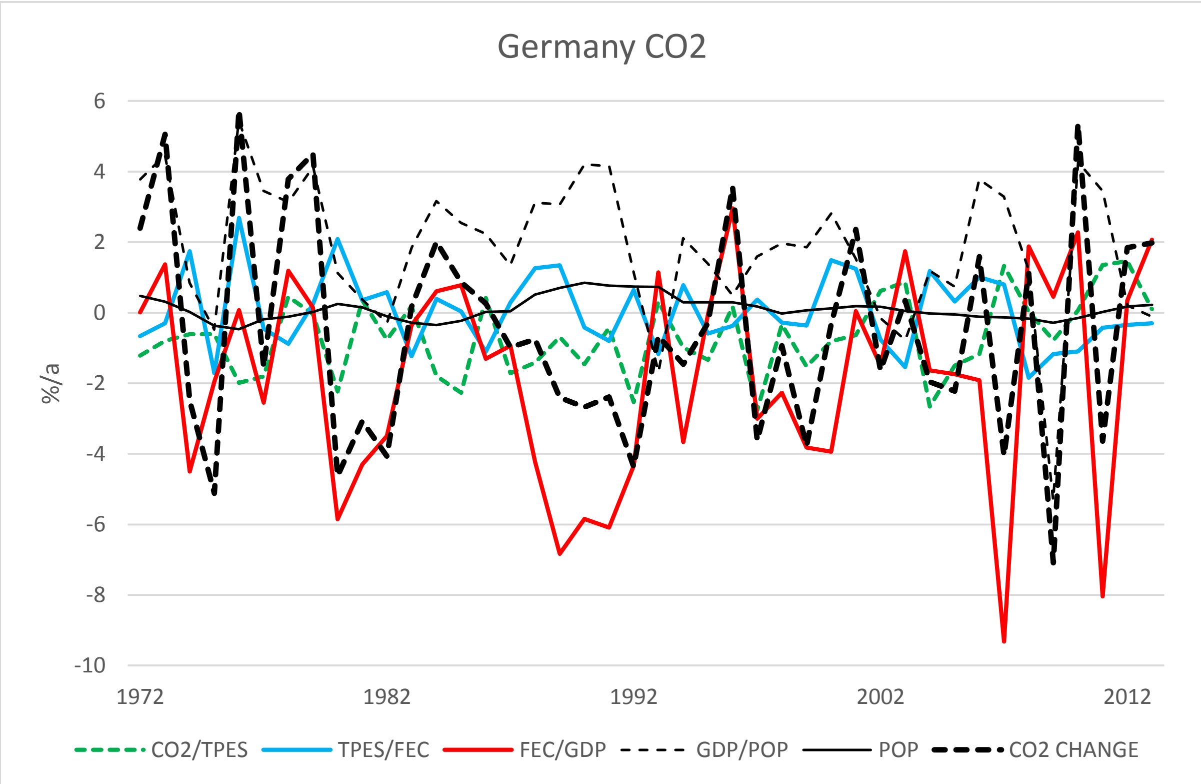
TPES change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GDP/POP
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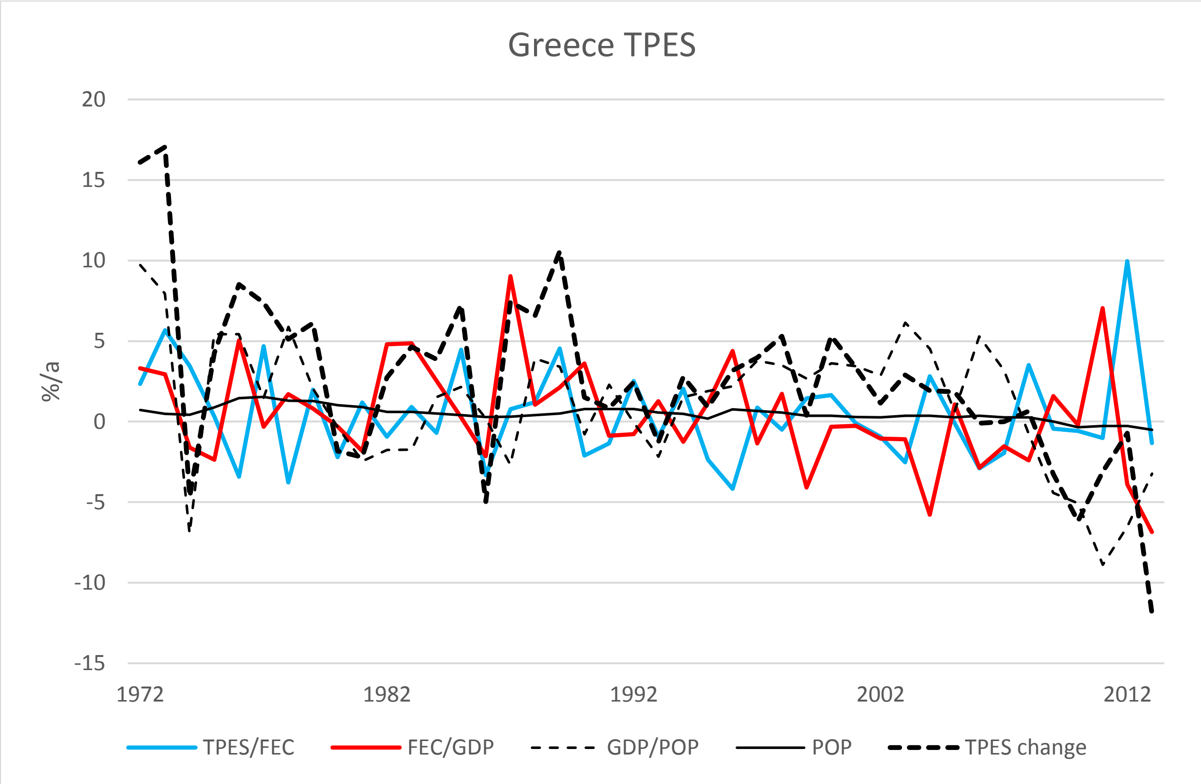
CO2 CHANGE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GDP/POP
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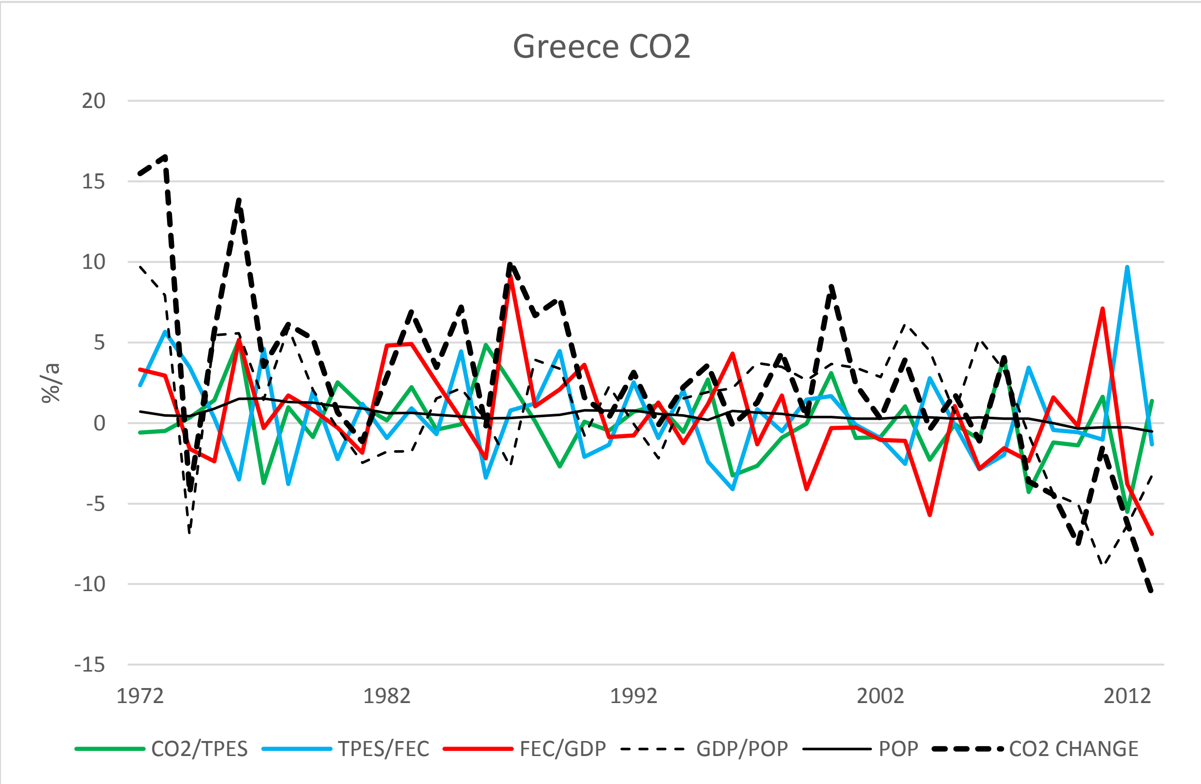
TPES change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TPES/FEC
FEC/GDP
GDP/POP
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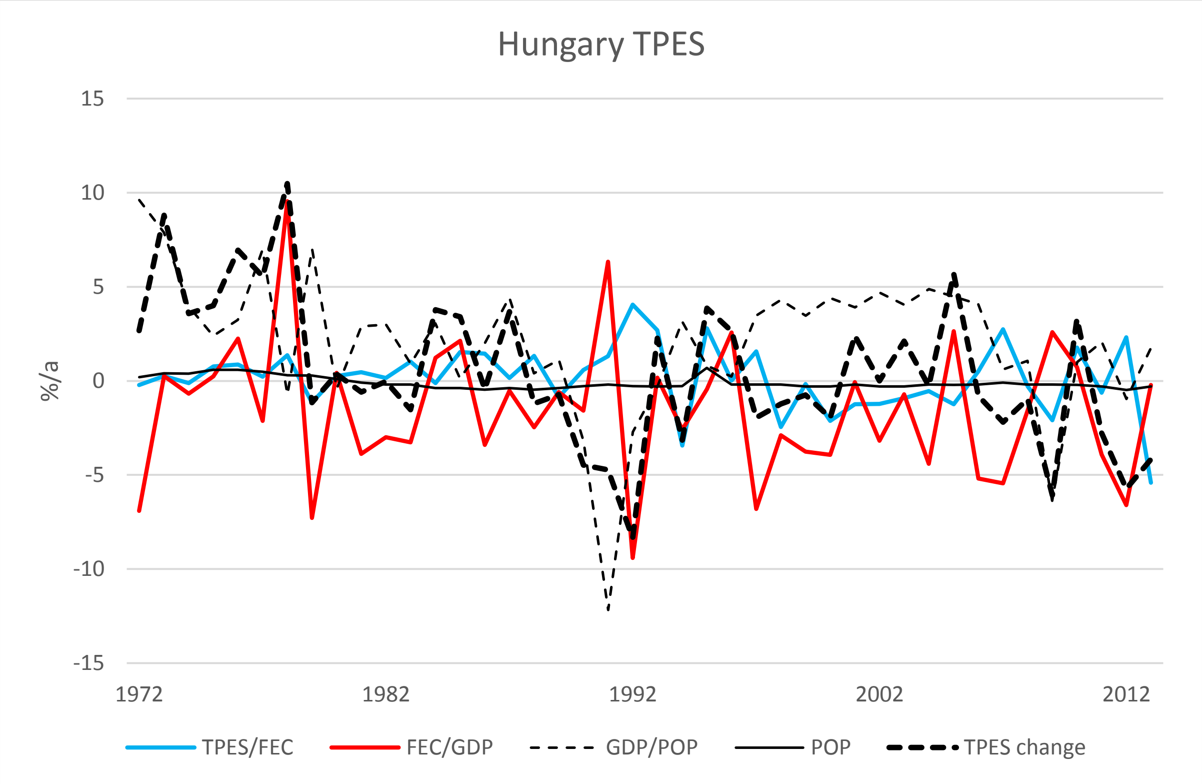
CO2 CHANGE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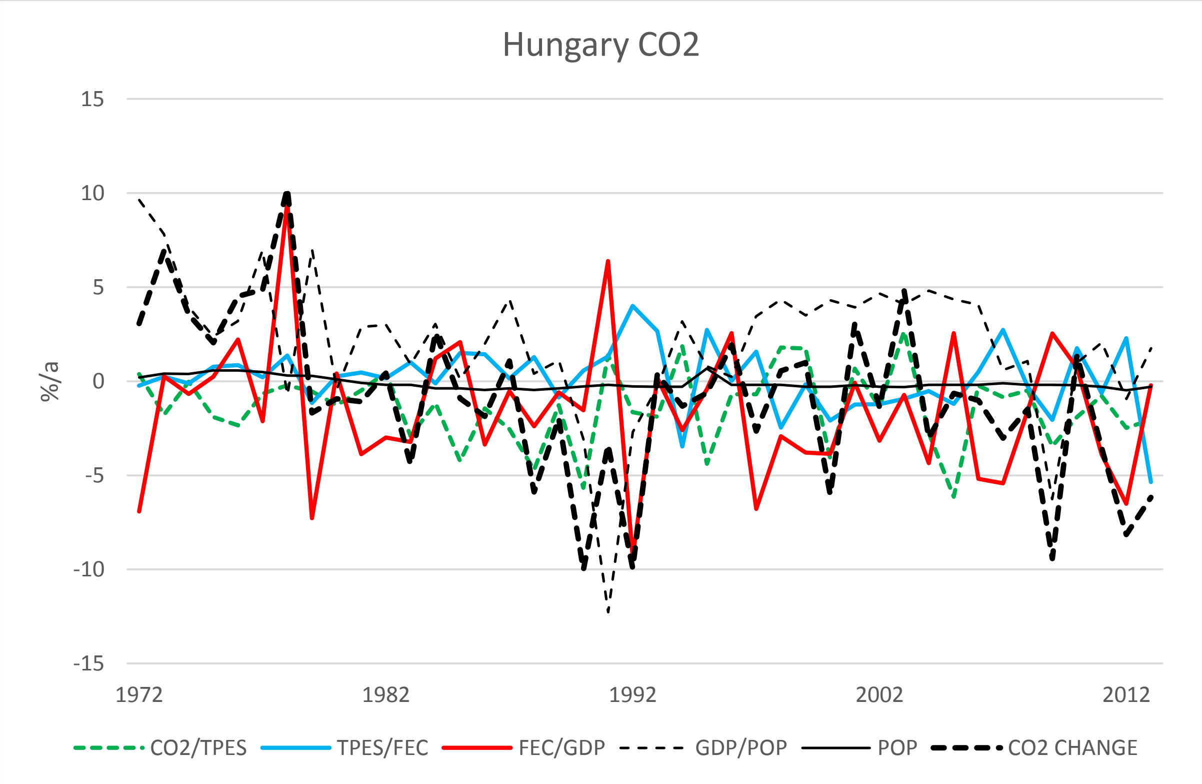
GDP/POP
POP
TPES change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TPES/FEC
FEC/GDP
GDP/POP
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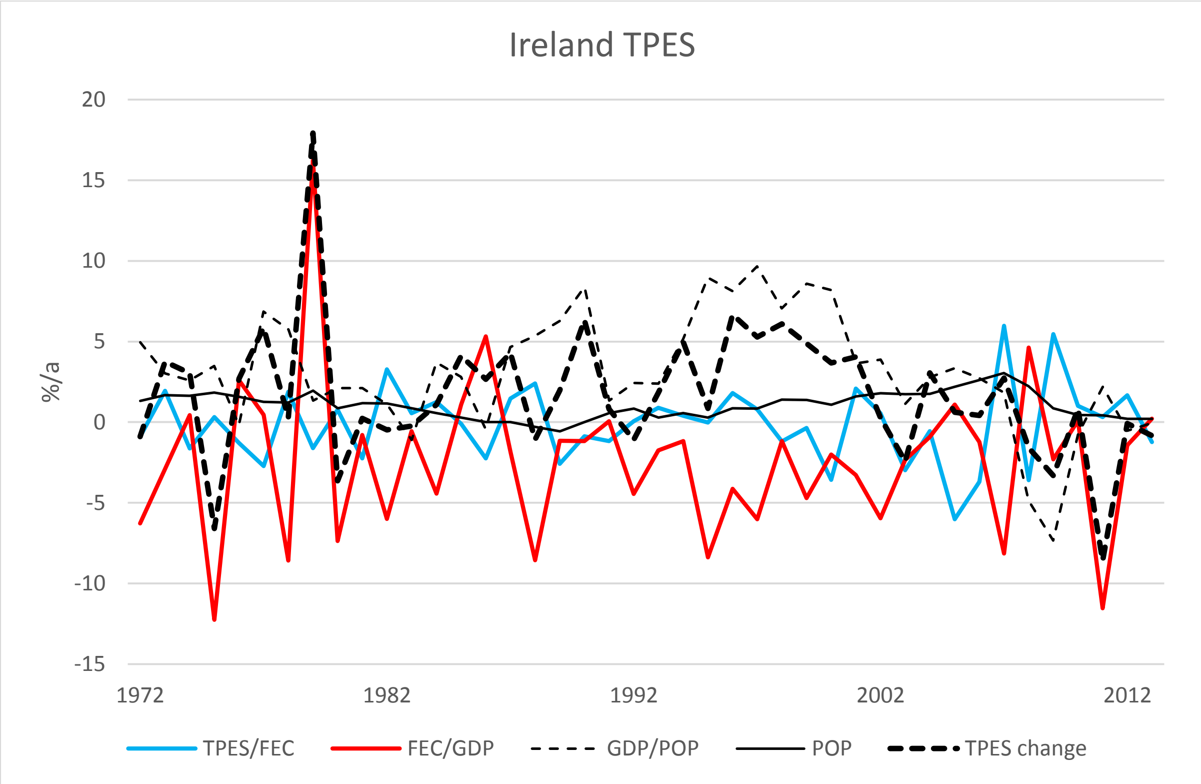
CO2 CHANGE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GDP/POP
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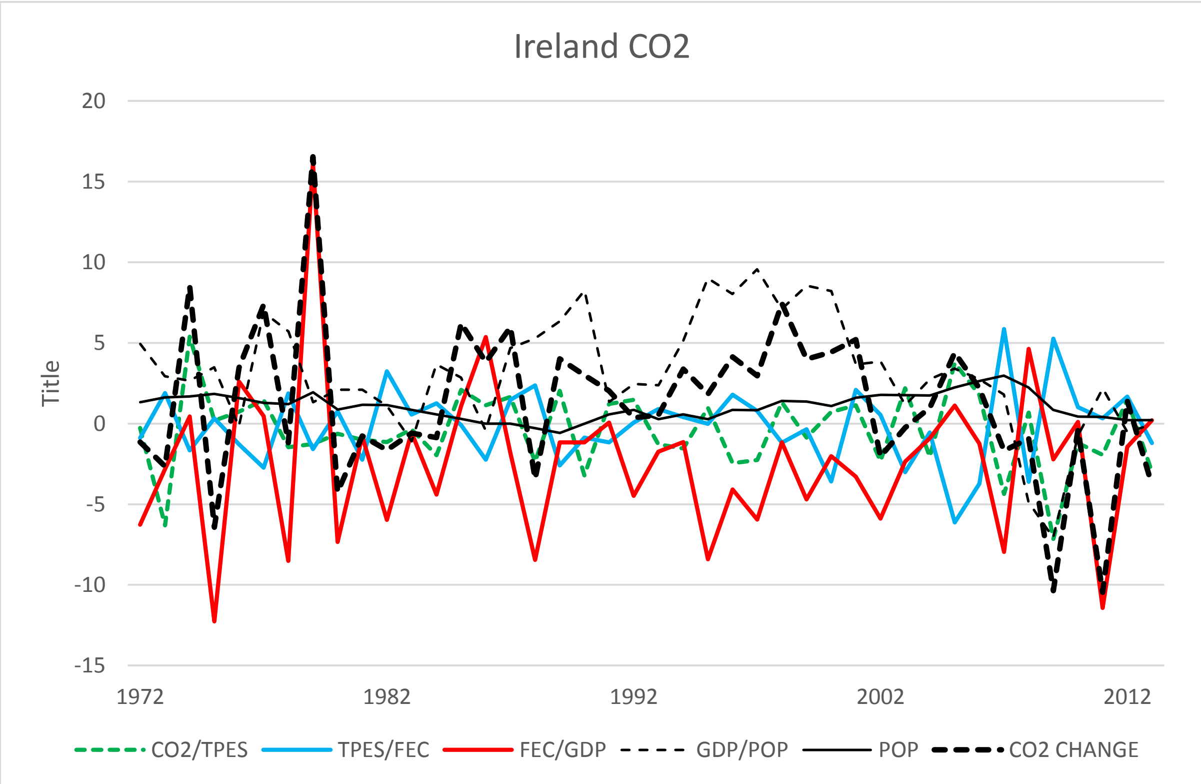
TPES change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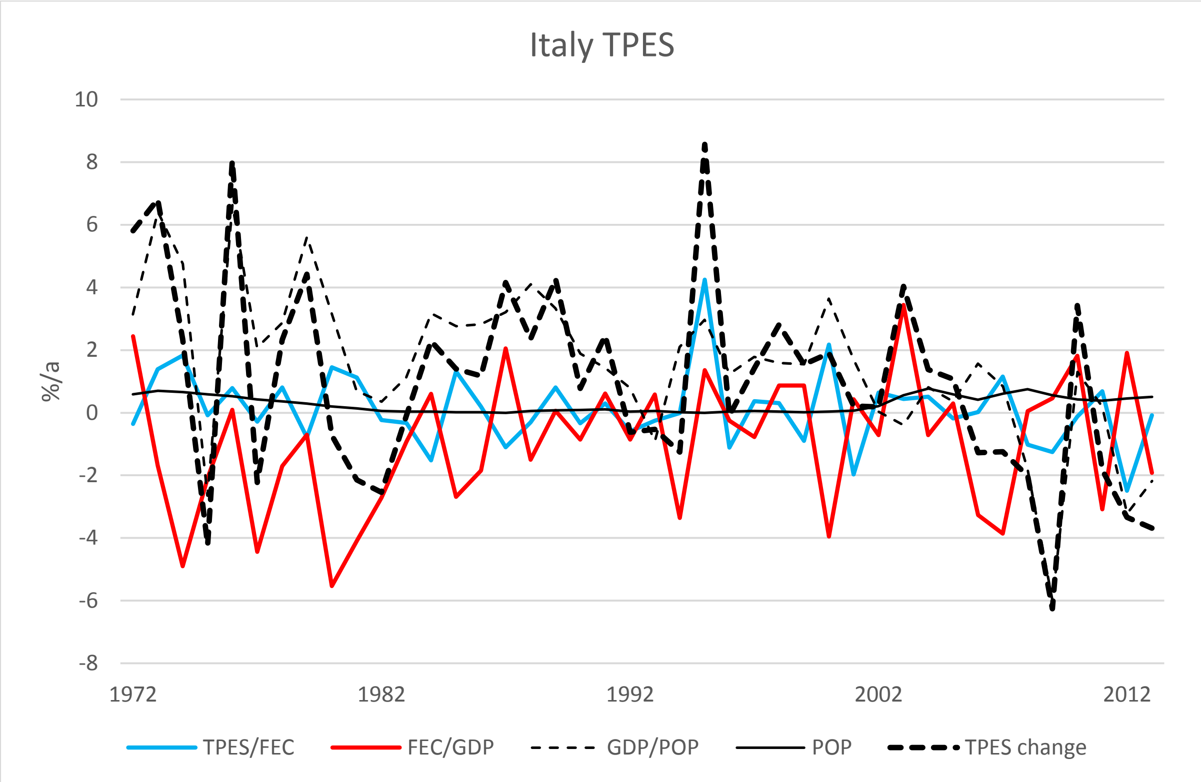
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE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%/a
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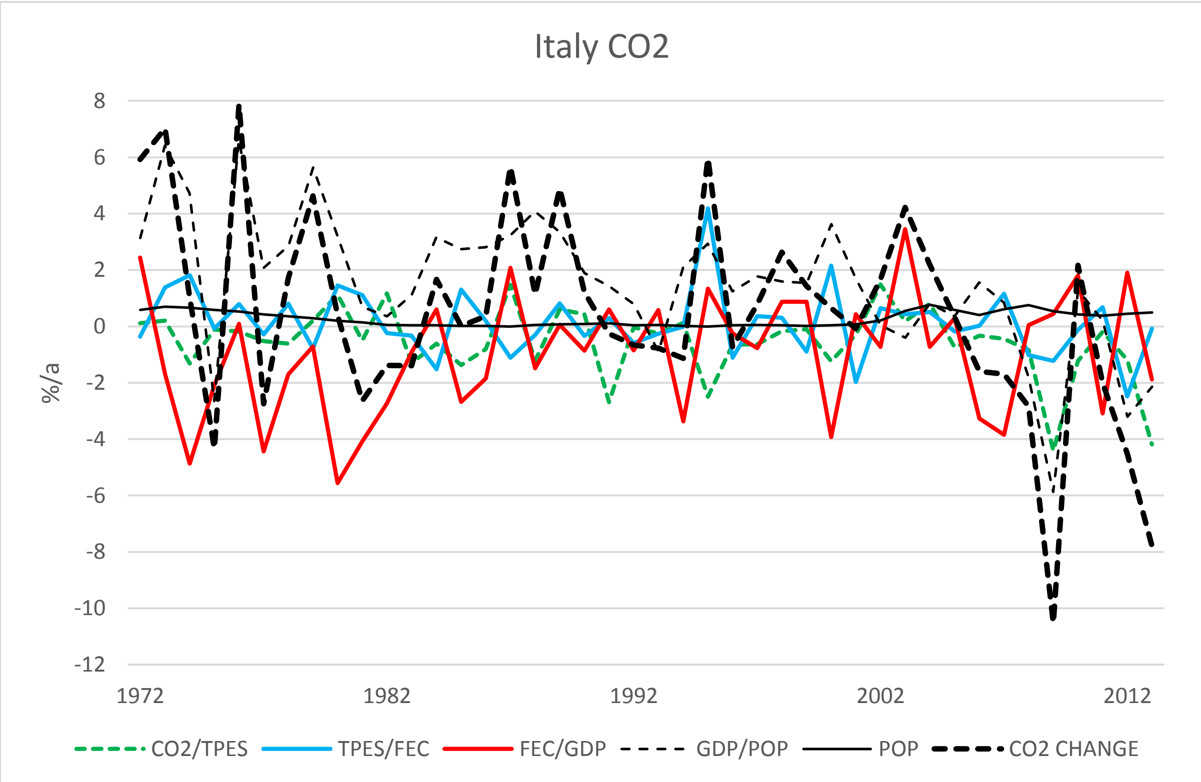
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change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%/a
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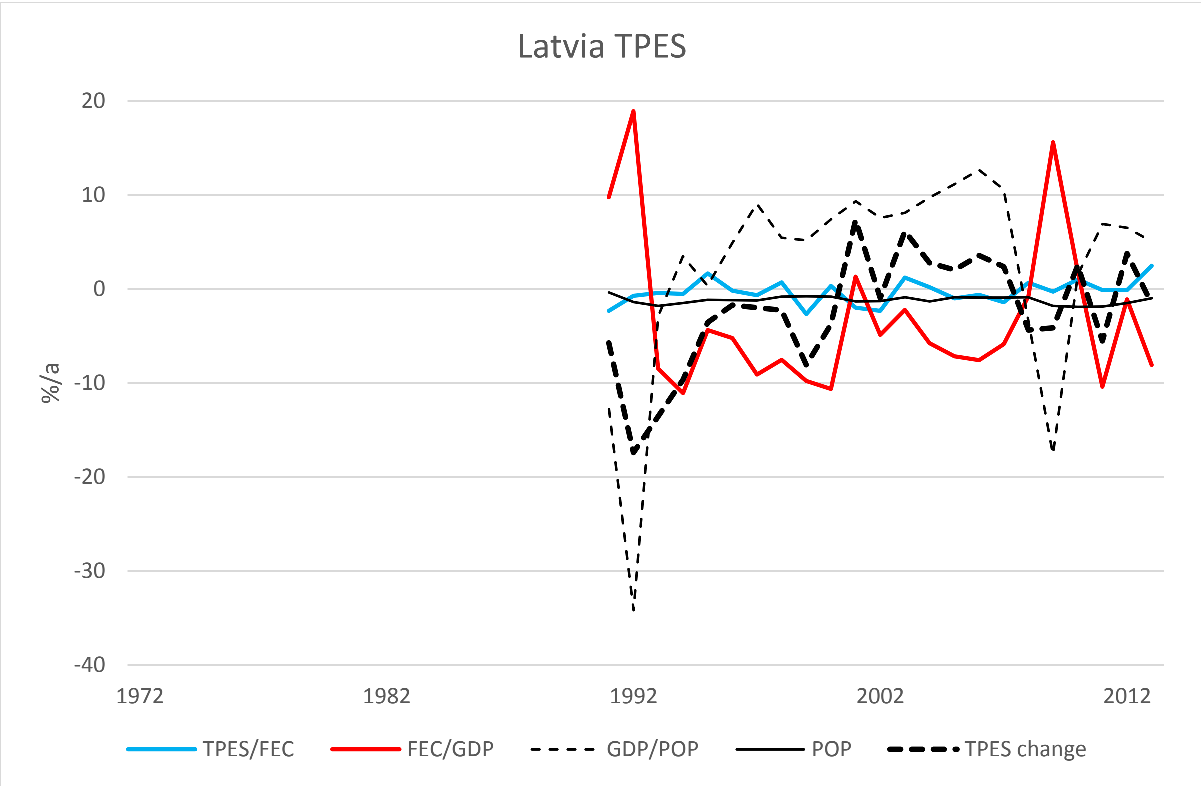
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE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1982
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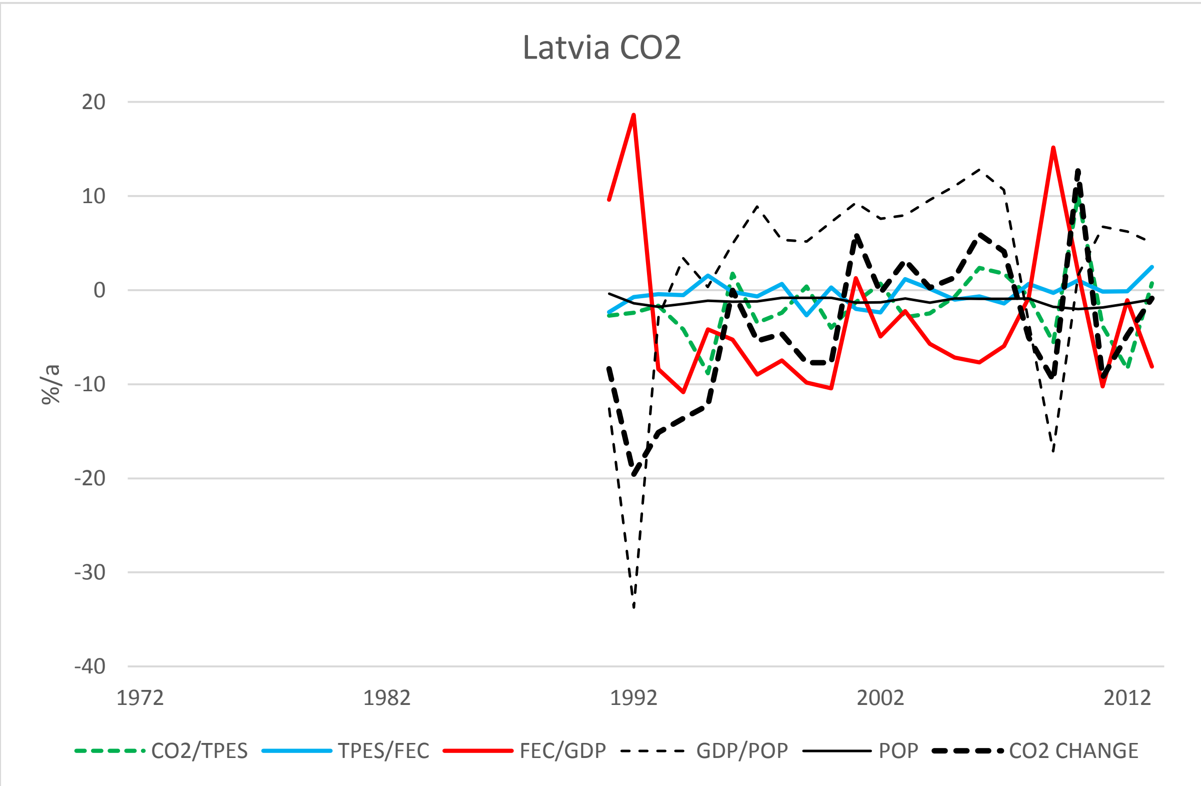
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change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10
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-10
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%/a
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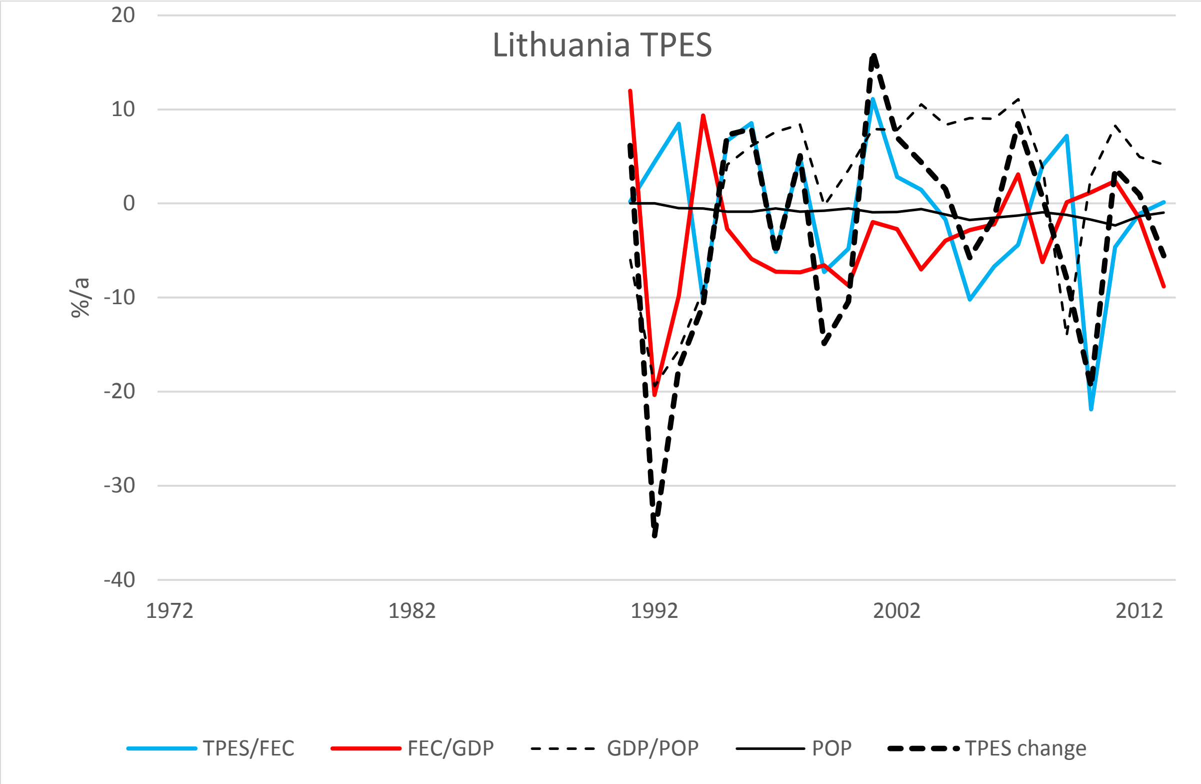
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE


Lithuania TPES
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GDP/POP
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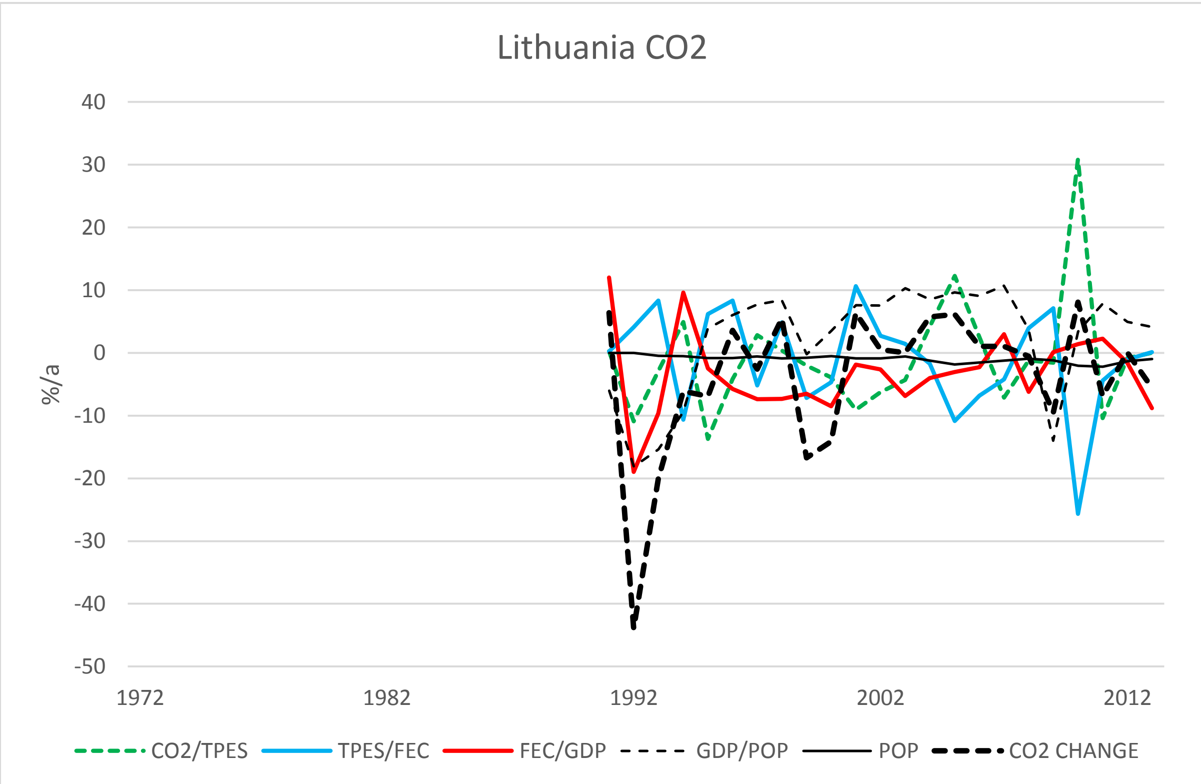
TPES change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-40
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2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
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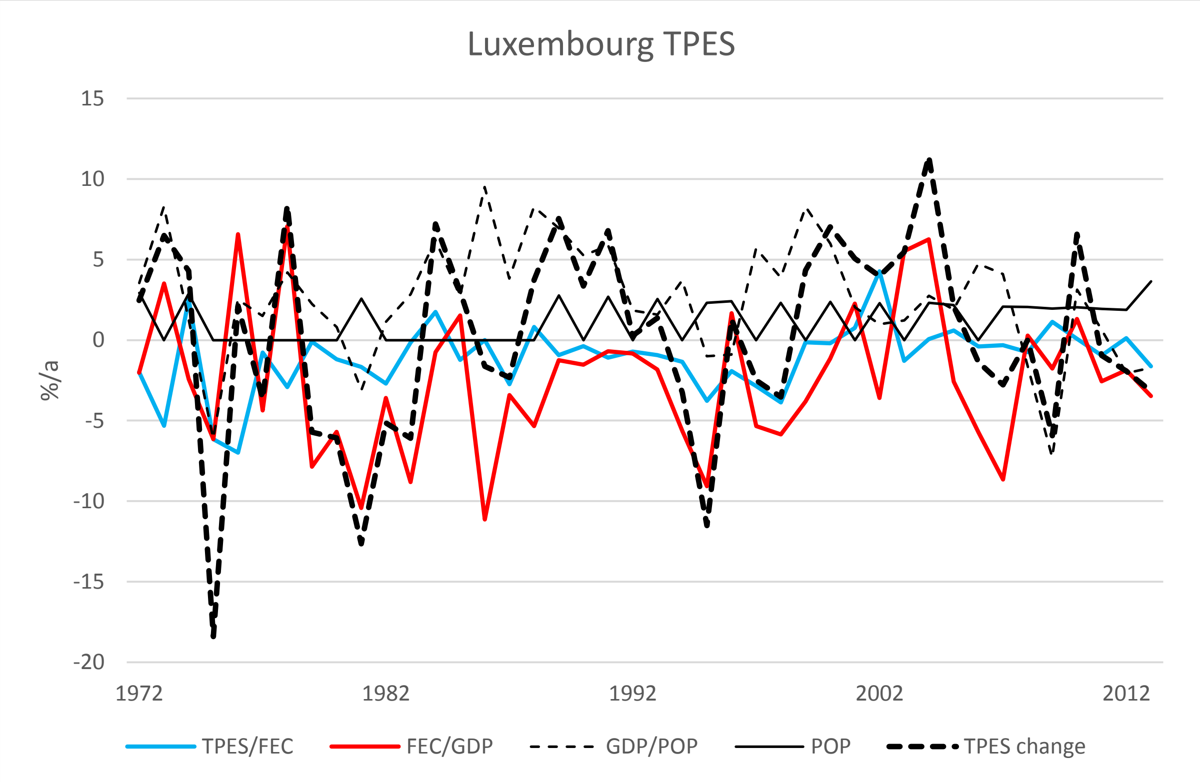
CO2 CHANGE


Luxembourg TPES
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5
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FEC/GDP
GDP/POP
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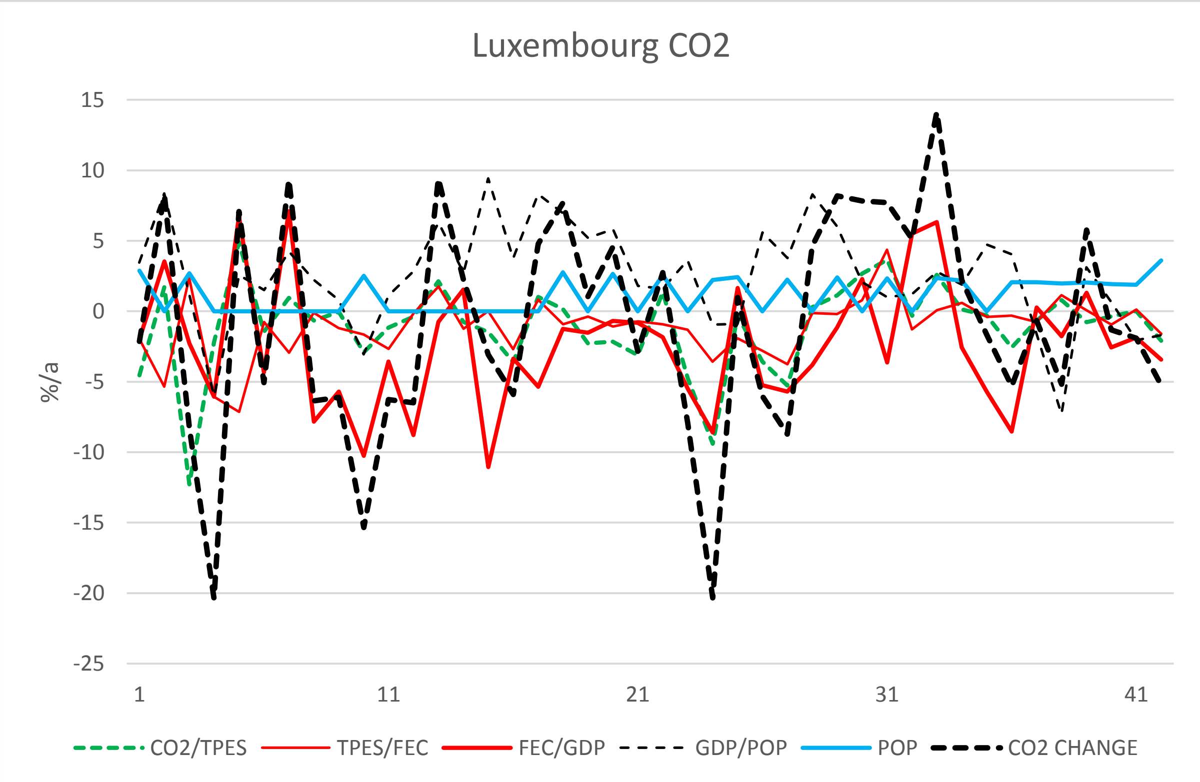
TPES change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TPES/FEC
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GDP/POP
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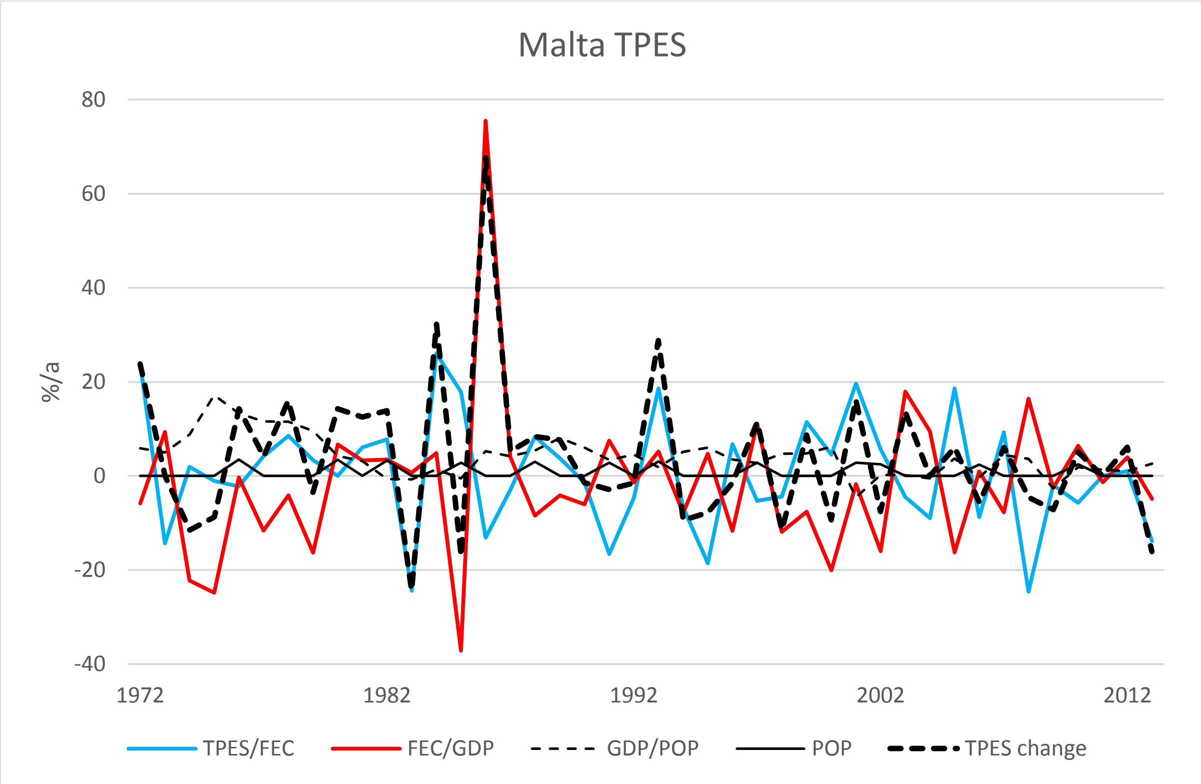
CO2 CHANGE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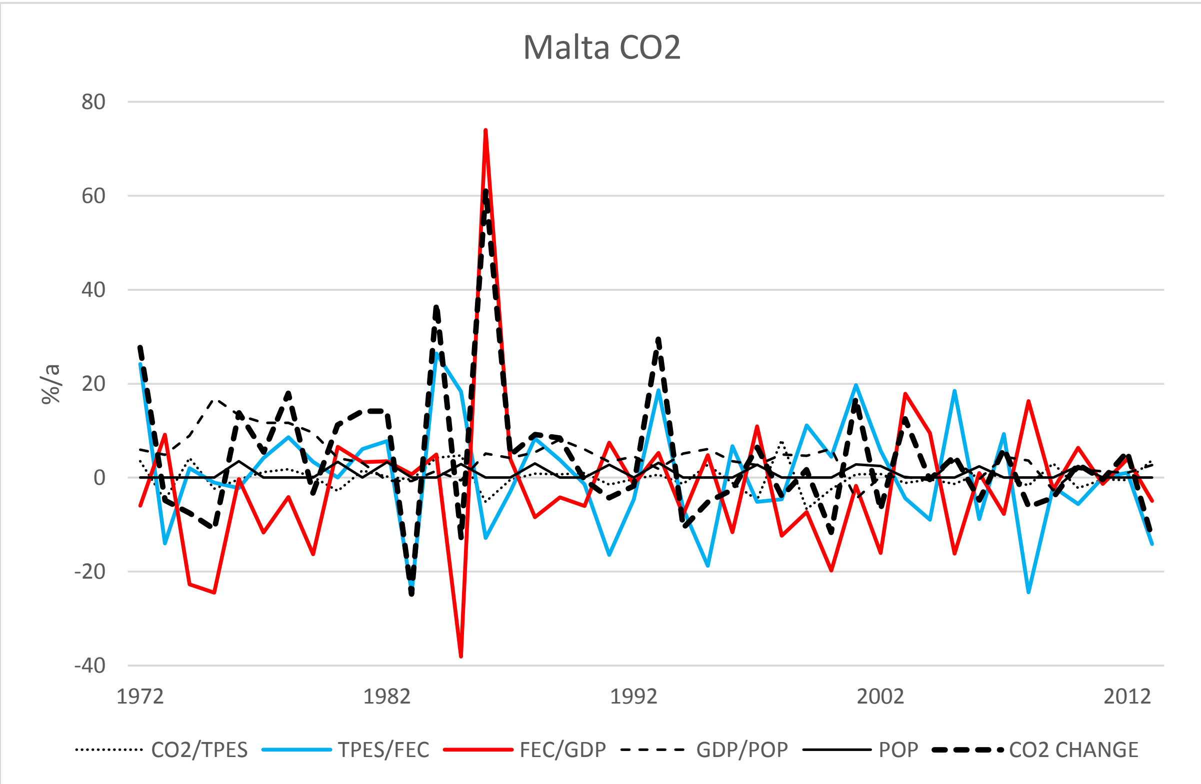
TPES change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TPES/FEC
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GDP/POP
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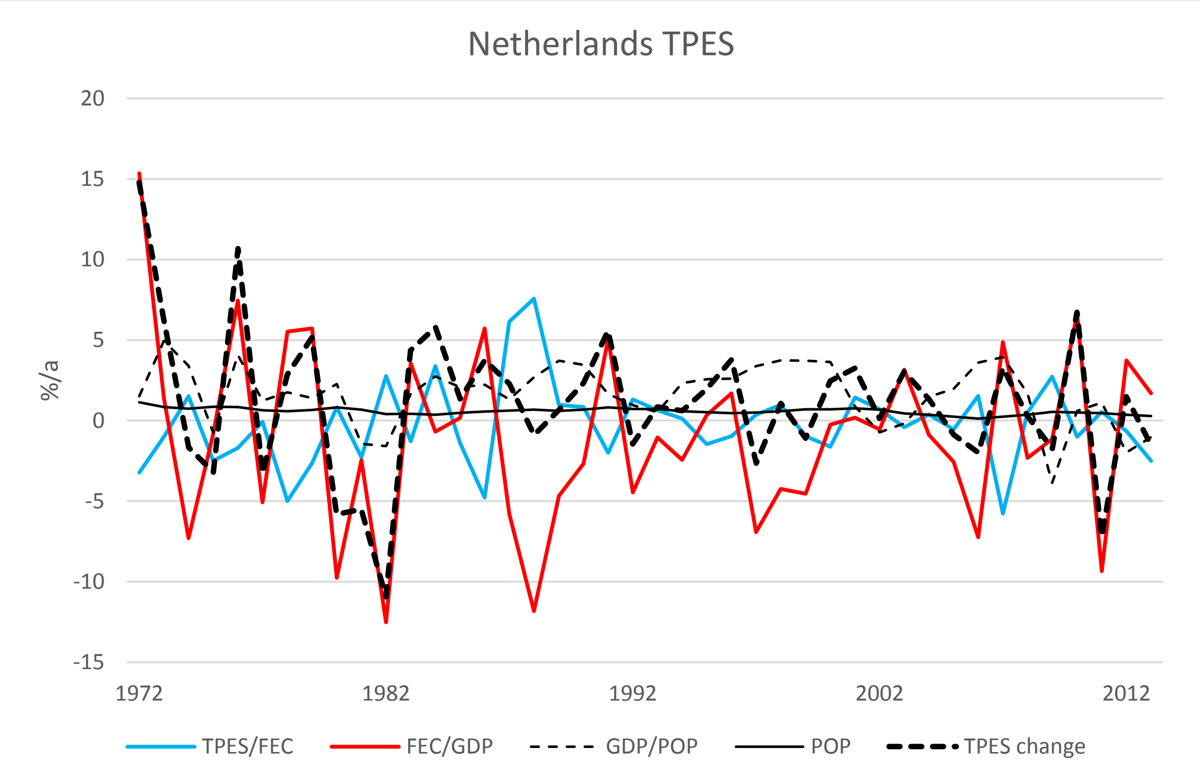
CO2 CHANGE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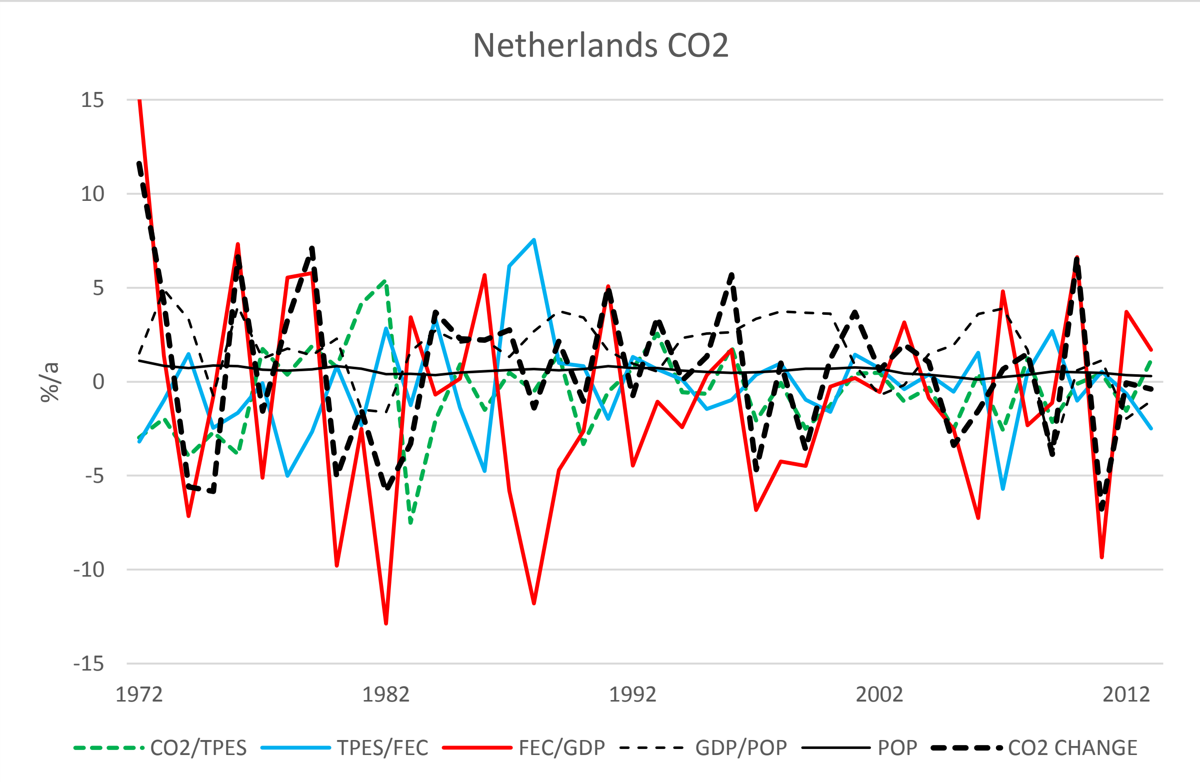
TPES change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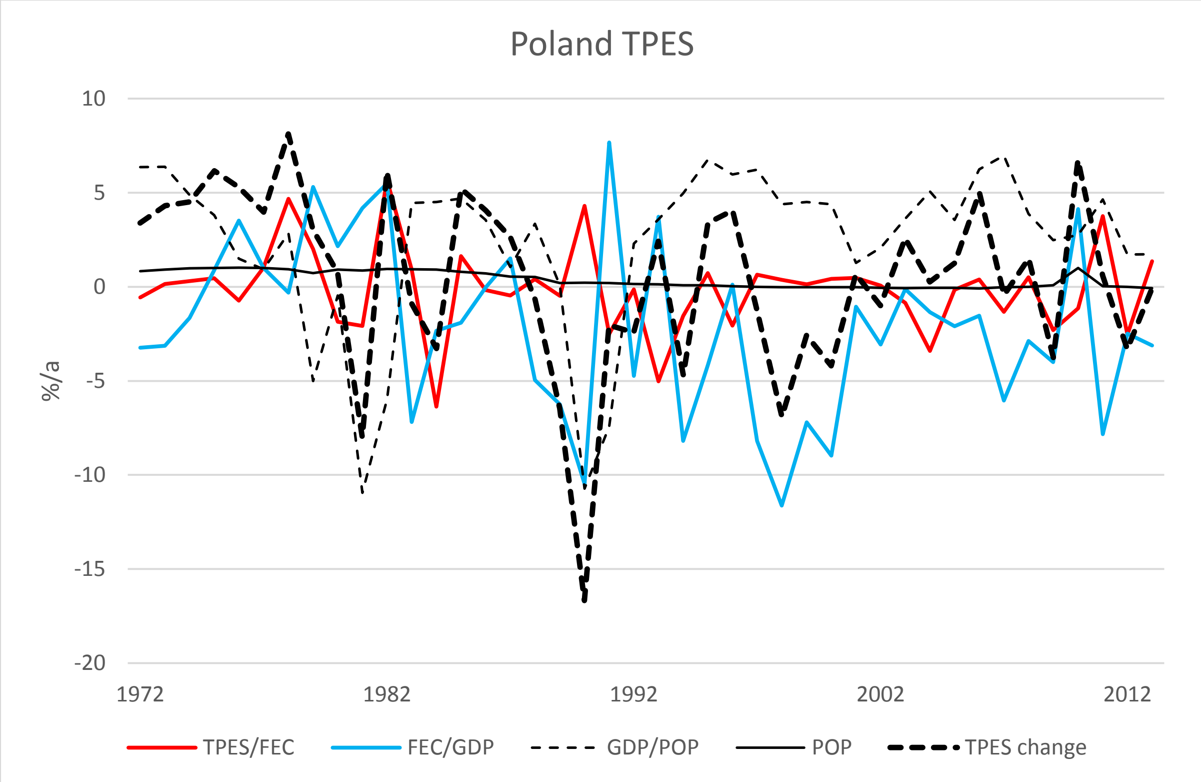
CO2 CHANGE



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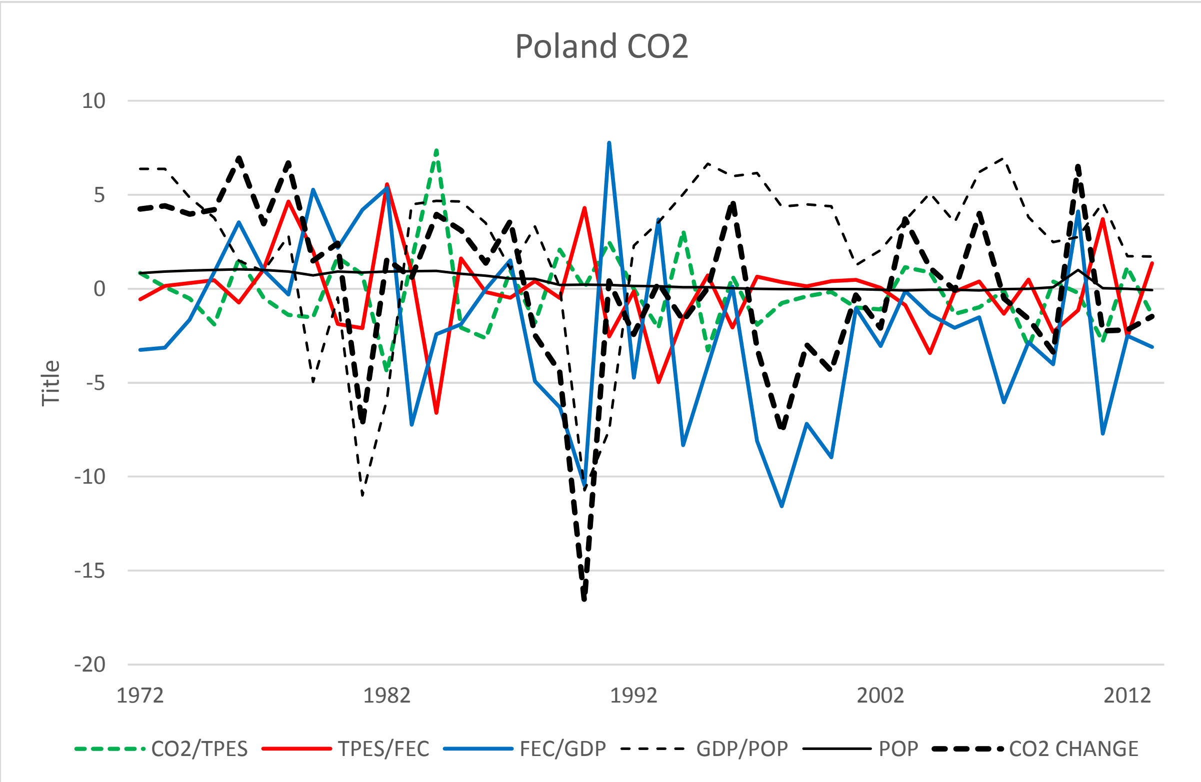
TPES change



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TPES/FEC
FEC/GDP
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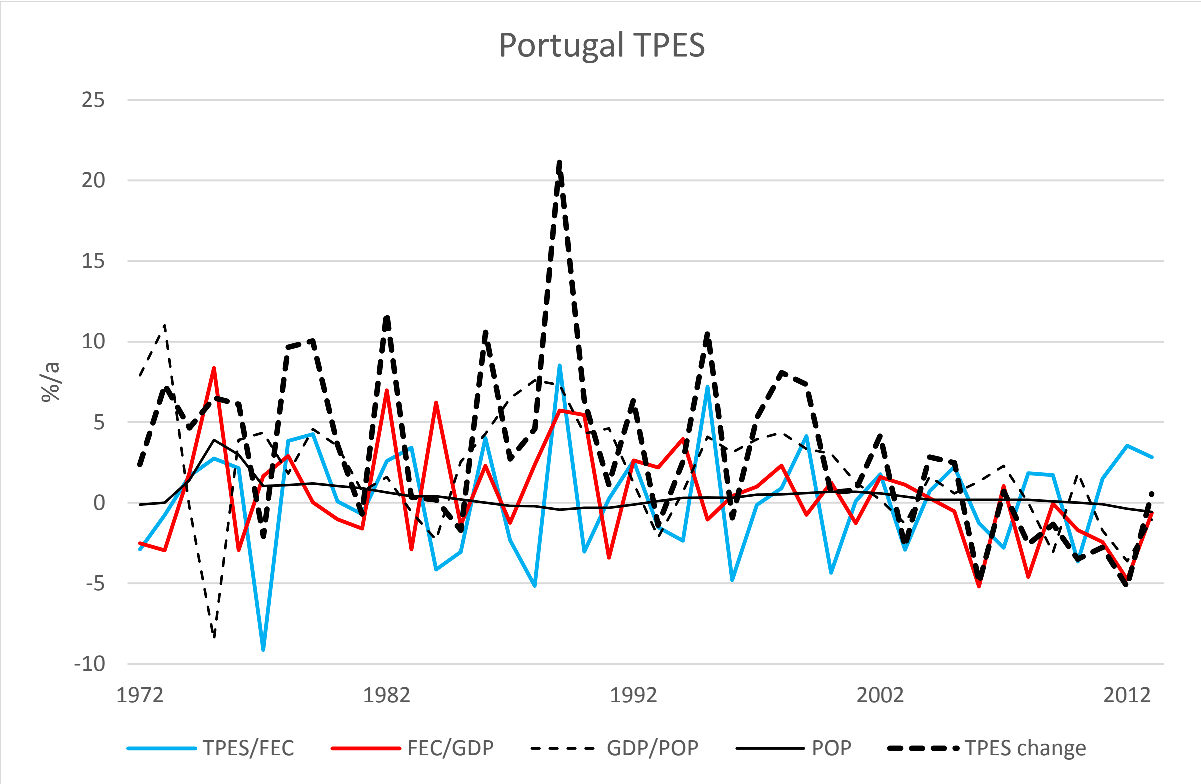
CO2 CHANGE



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GDP/POP
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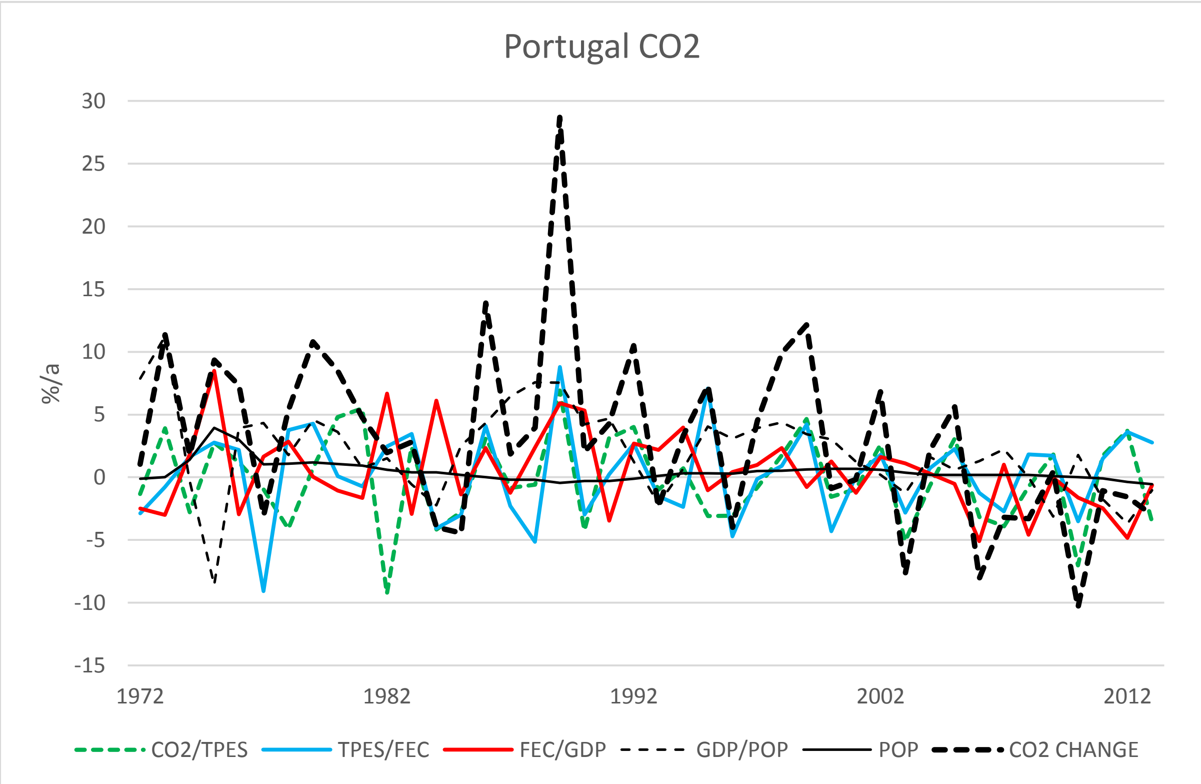
TPES change



Portugal CO2
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TPES/FEC
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GDP/POP
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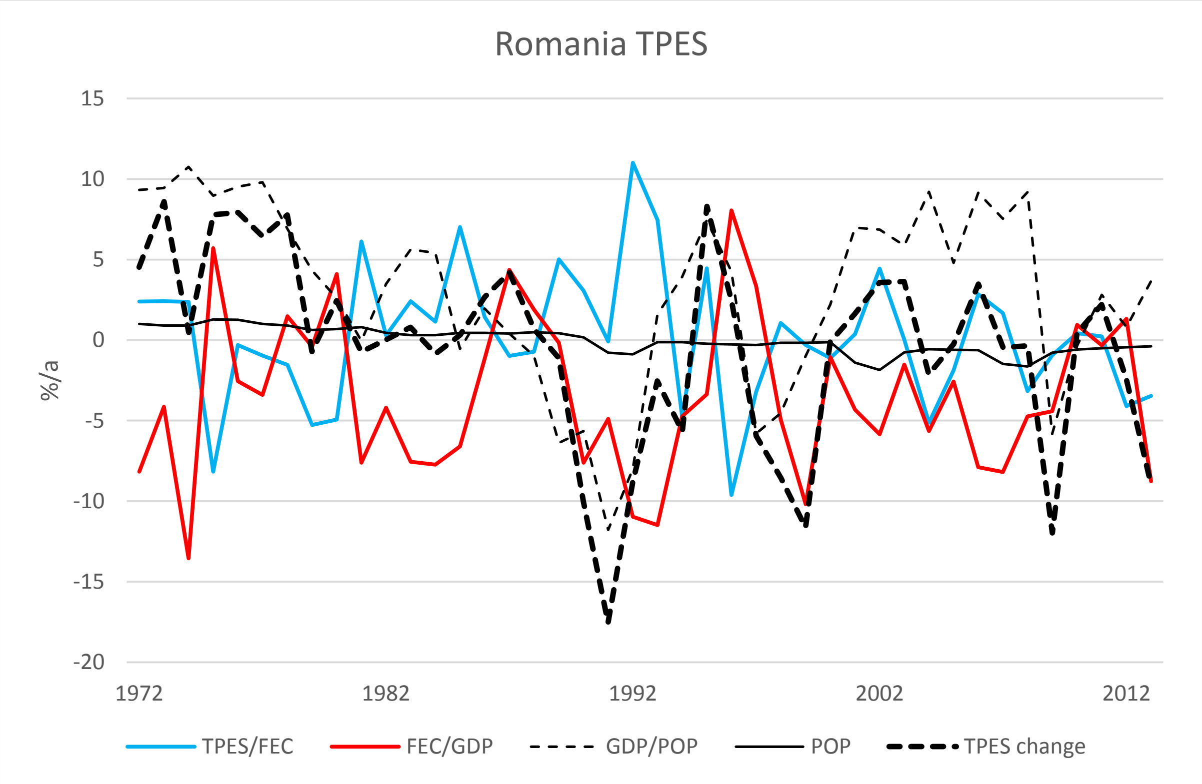
CO2 CHANGE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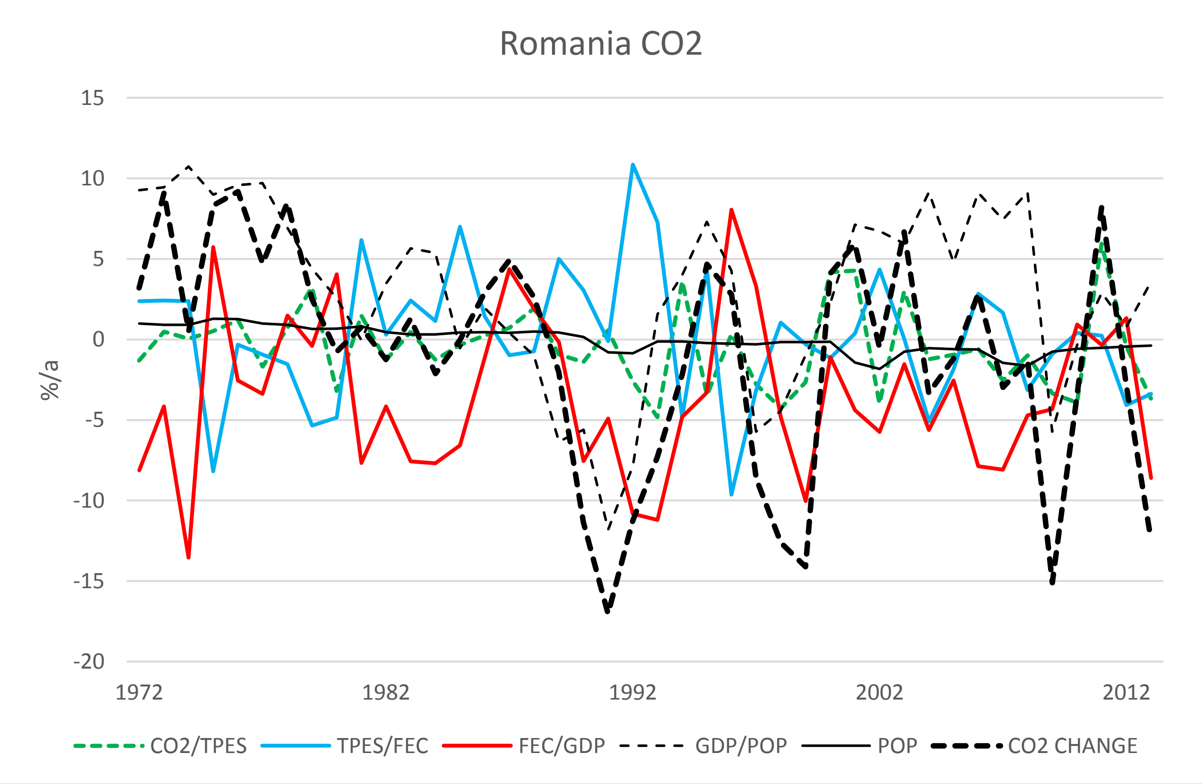
GDP/POP
POP
TPES change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TPES/FEC
FEC/GDP
GDP/POP
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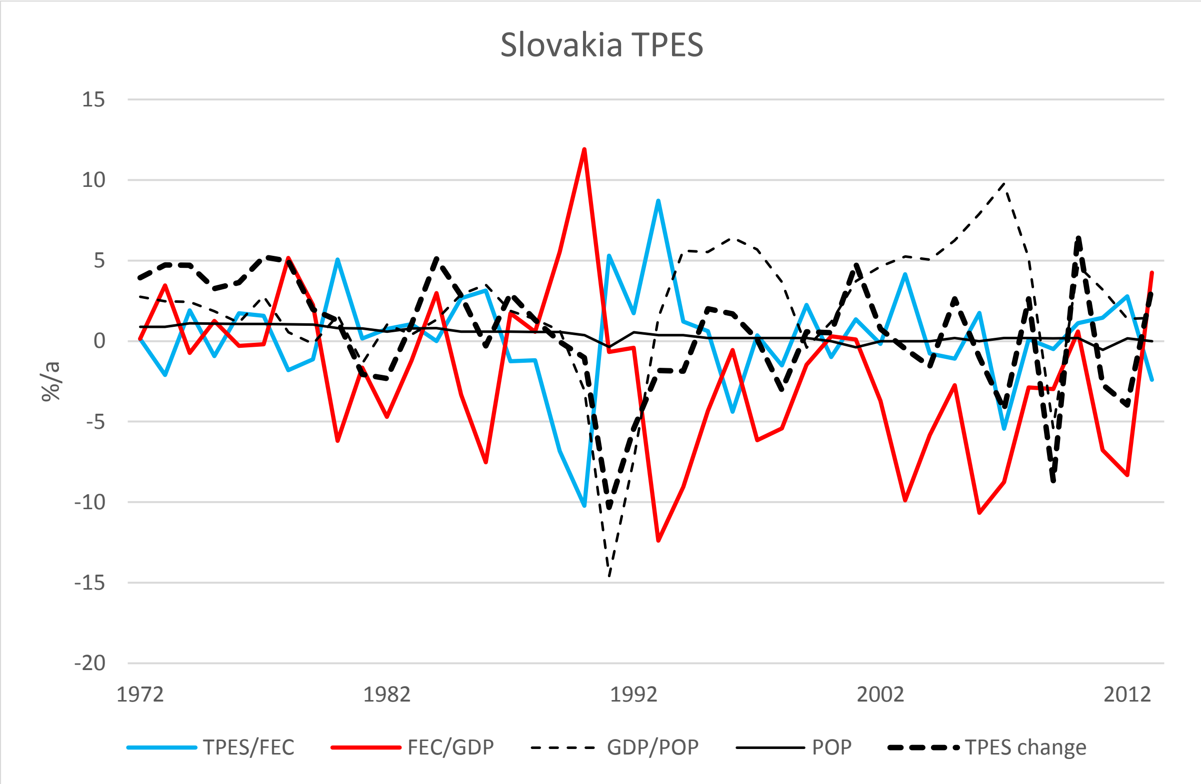
CO2 CHANGE


Slovakia TPES
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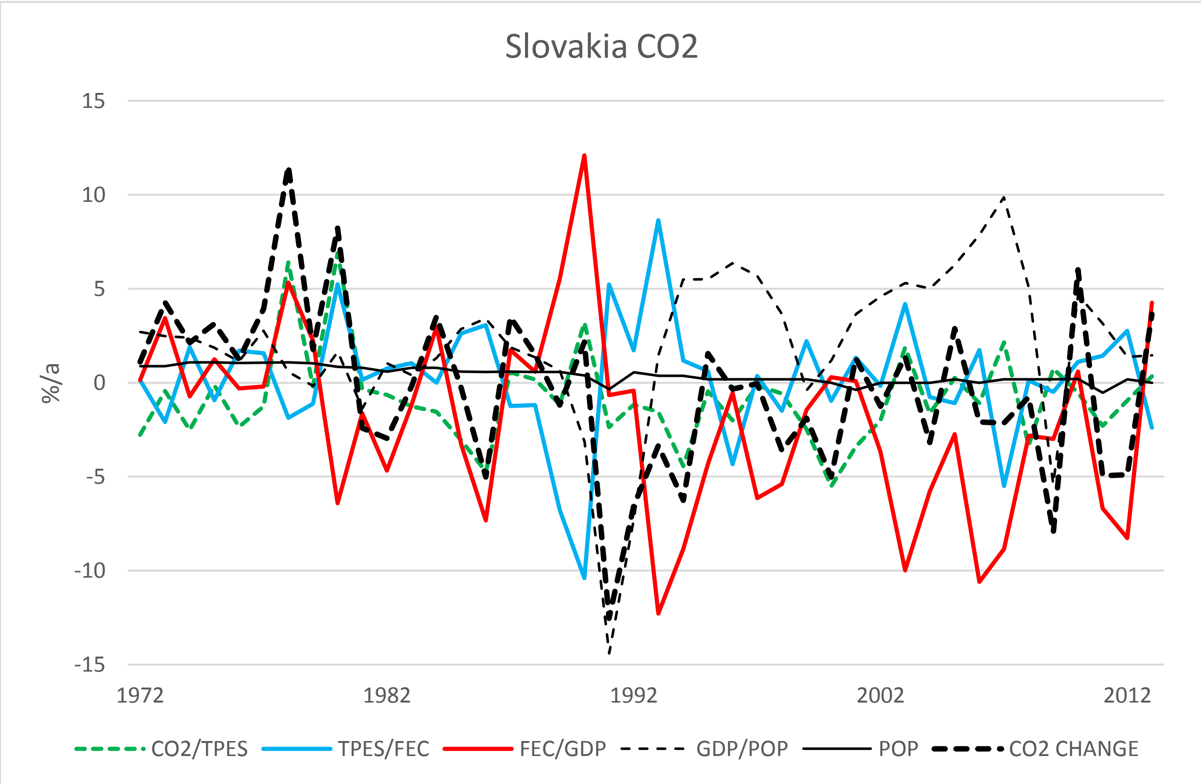
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change


Slovakia CO2
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CO2/TPES
TPES/FEC
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GDP/POP
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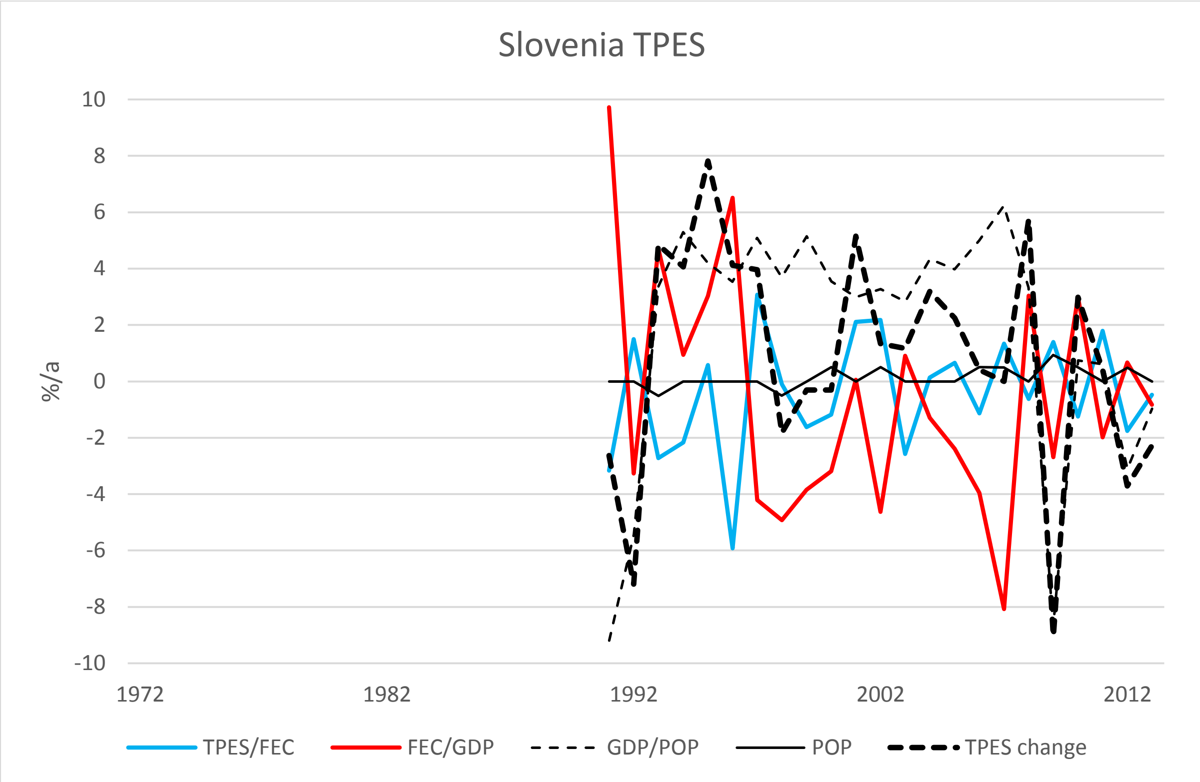
CO2 CHANGE


Slovenia TPES
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TPES/FEC
FEC/GDP
GDP/POP
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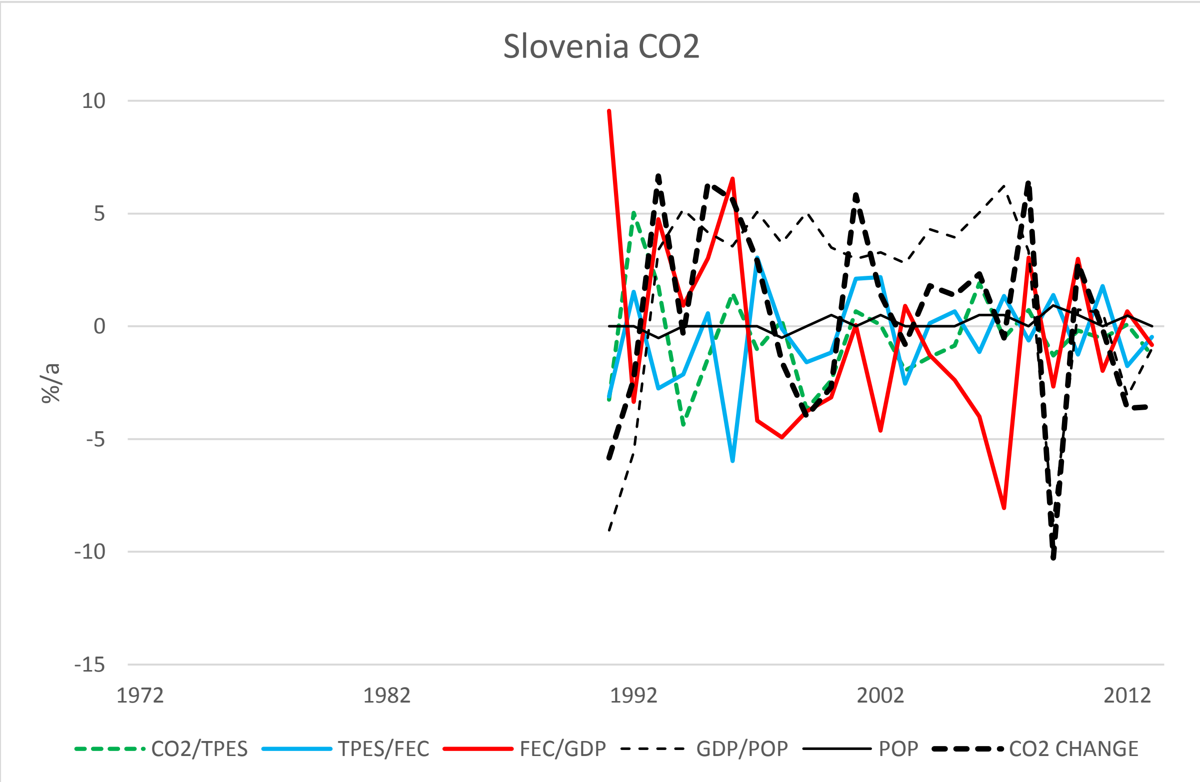
TPES change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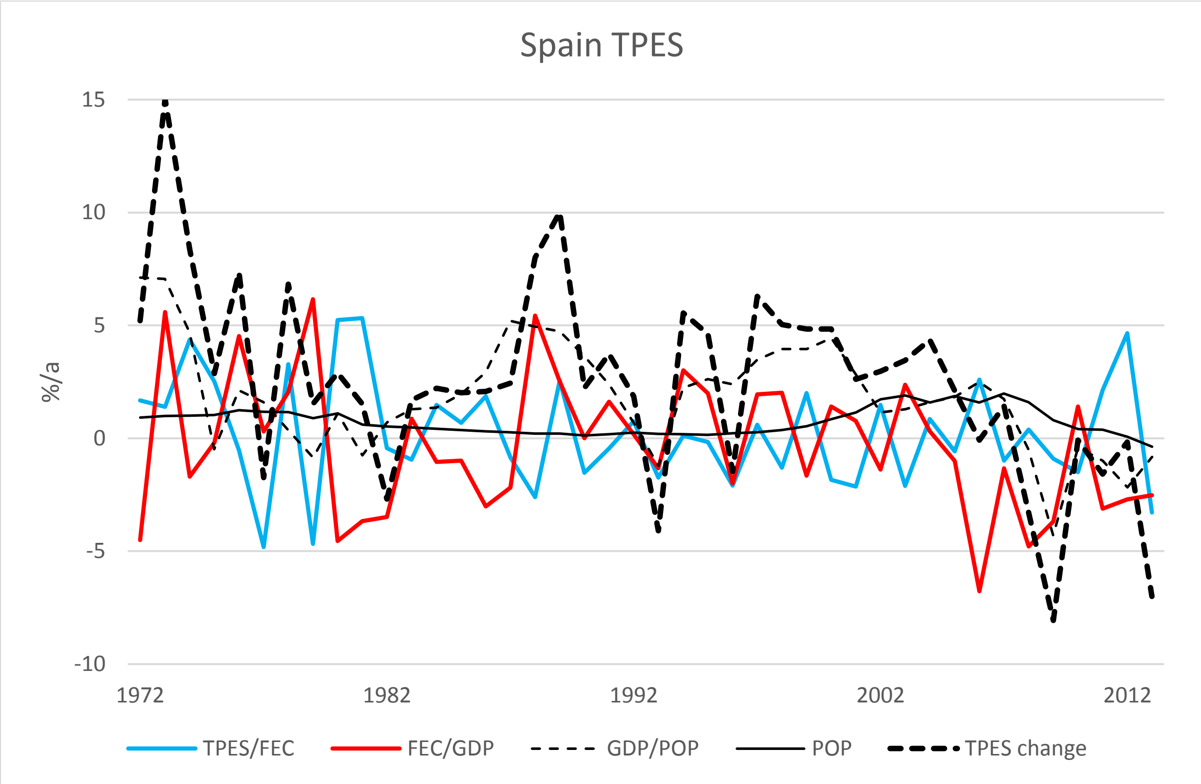
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE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FEC/GDP
GDP/POP
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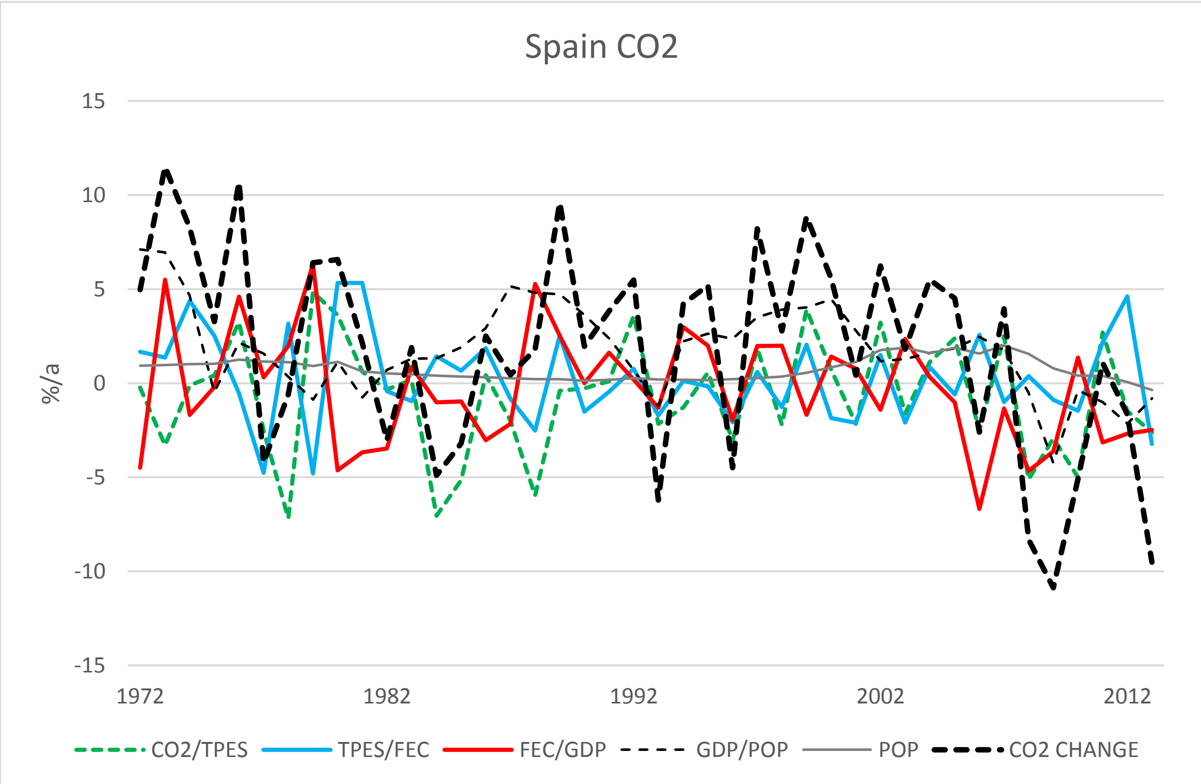
TPES change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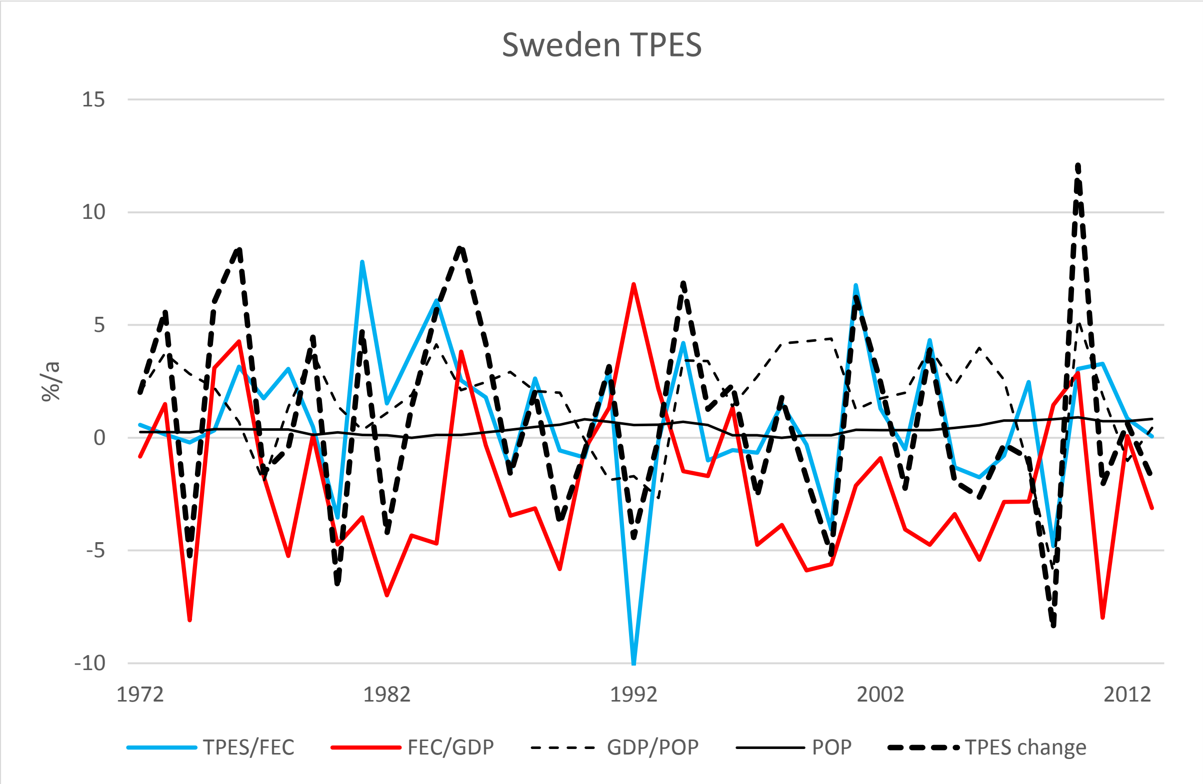
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE


Sweden TPES
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%/a
1972
1982
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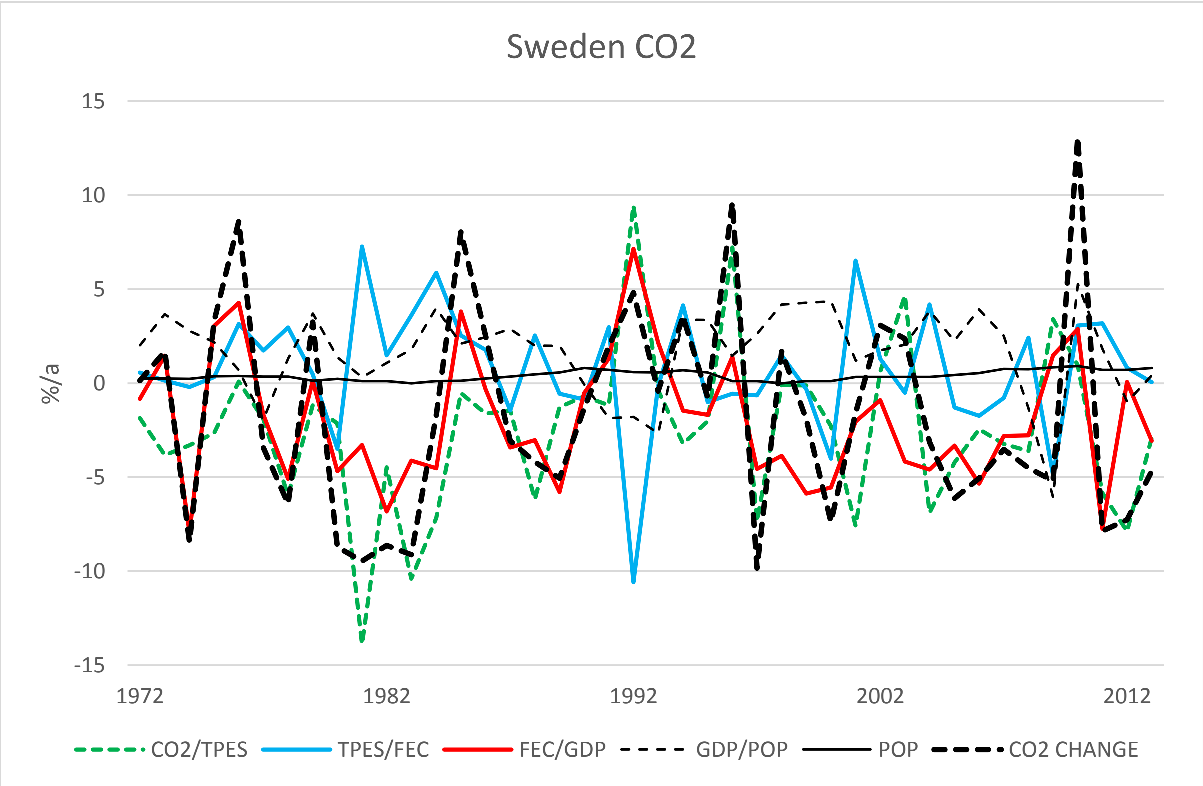
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change


Sweden CO2
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CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
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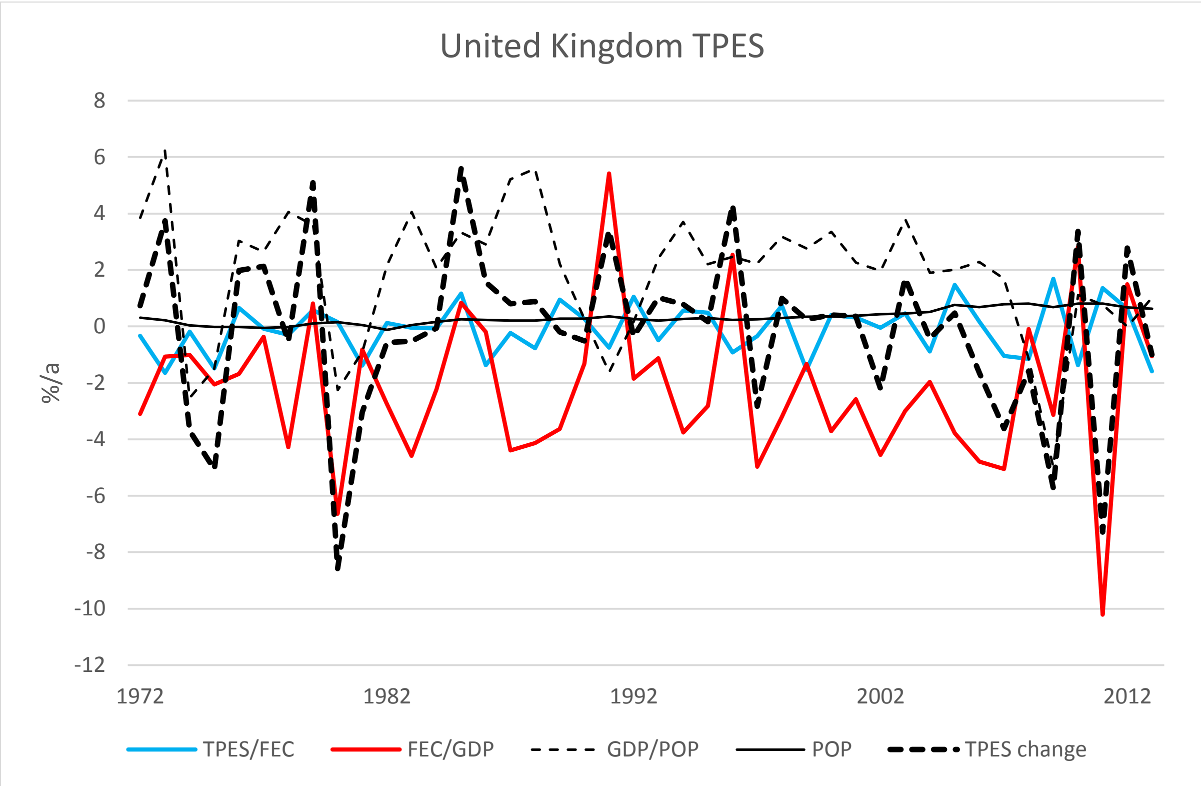
CO2 CHANGE


United Kingdom TPES
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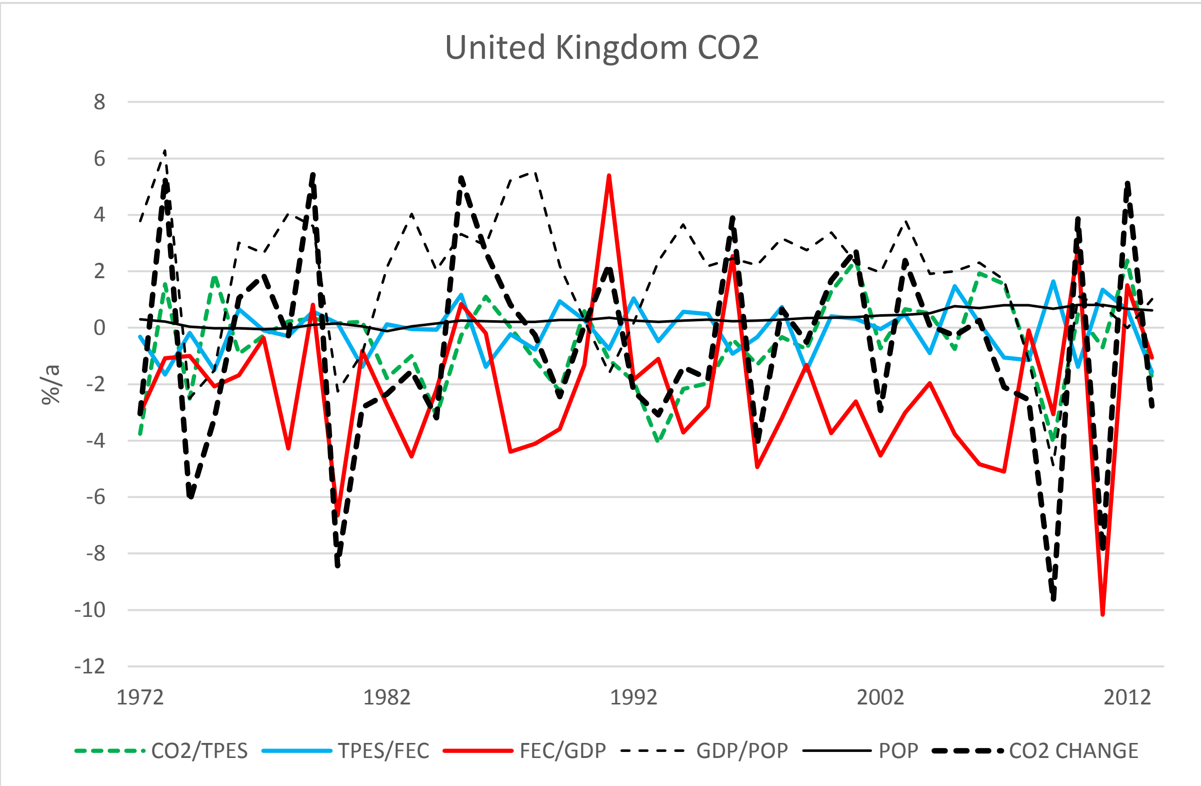
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change


United Kingdom CO2
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%/a
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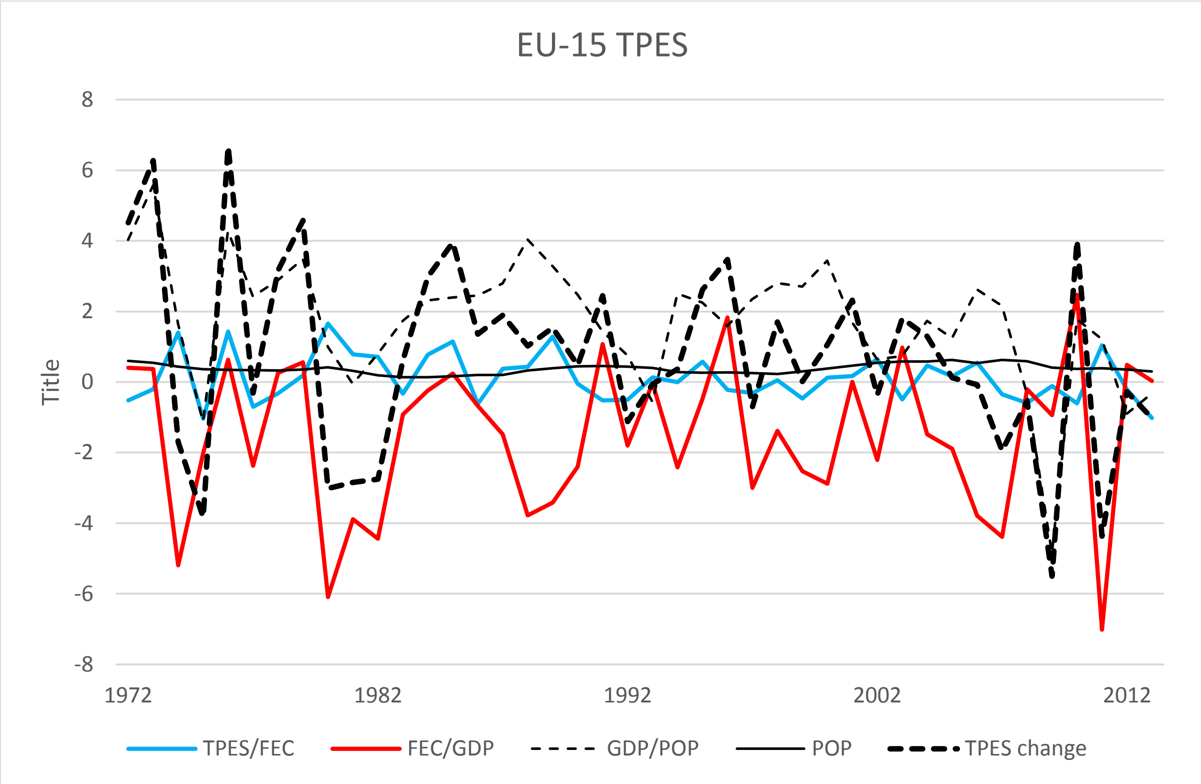
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE


EU-15 TPES
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Title
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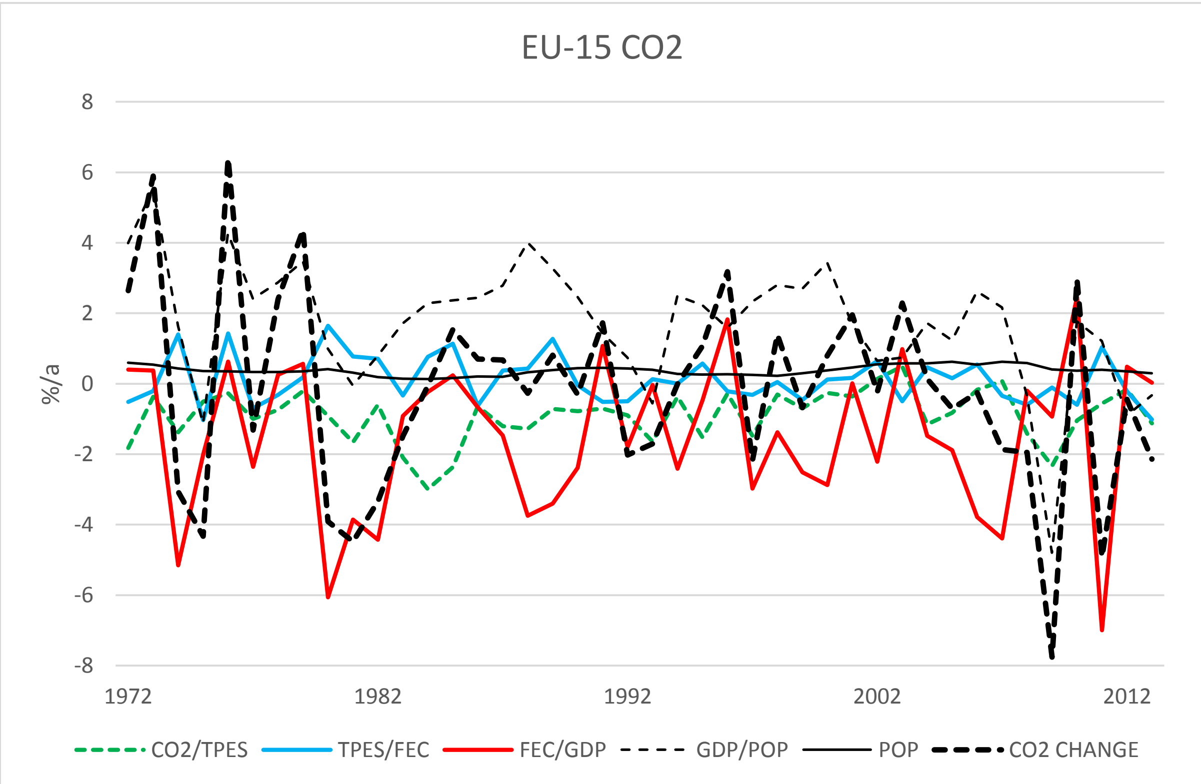
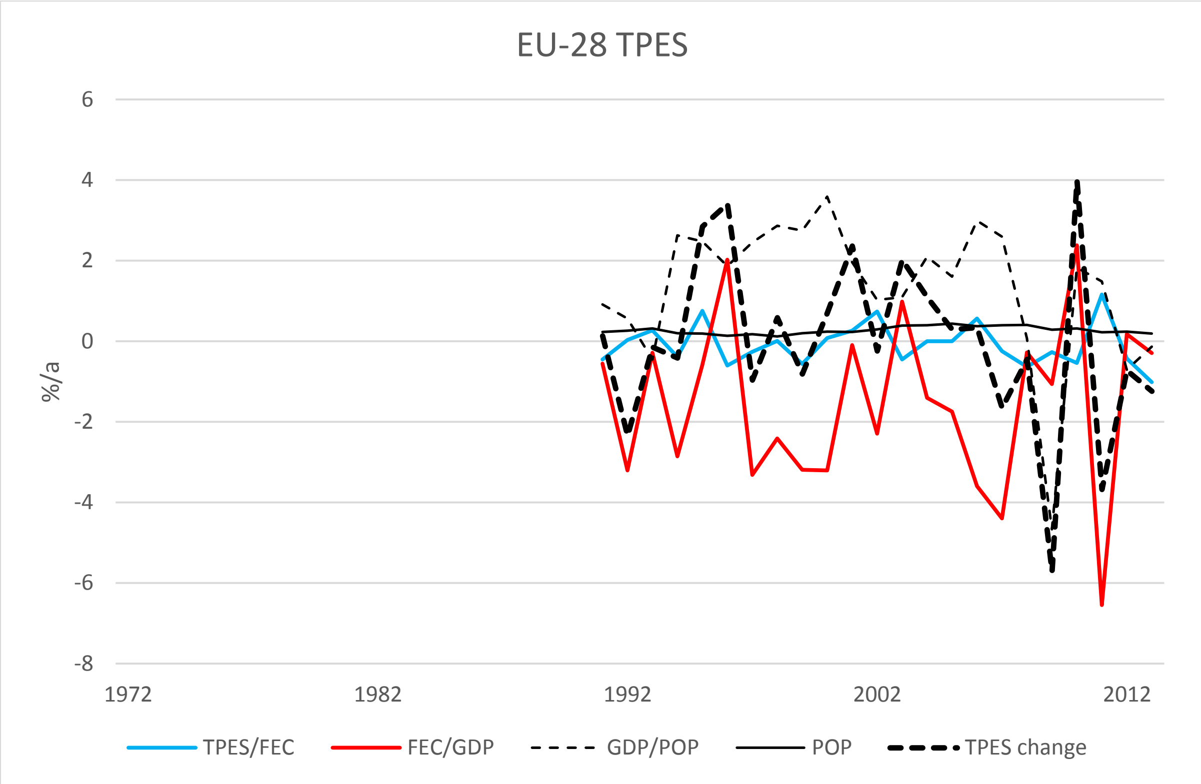
1992
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change


EU-15 CO2
8
6
4
2
0
-2
-4
-6
-8
%/a
1972
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE


EU-28 TPES
%/a
6
4
2
0
-2
-4
-6
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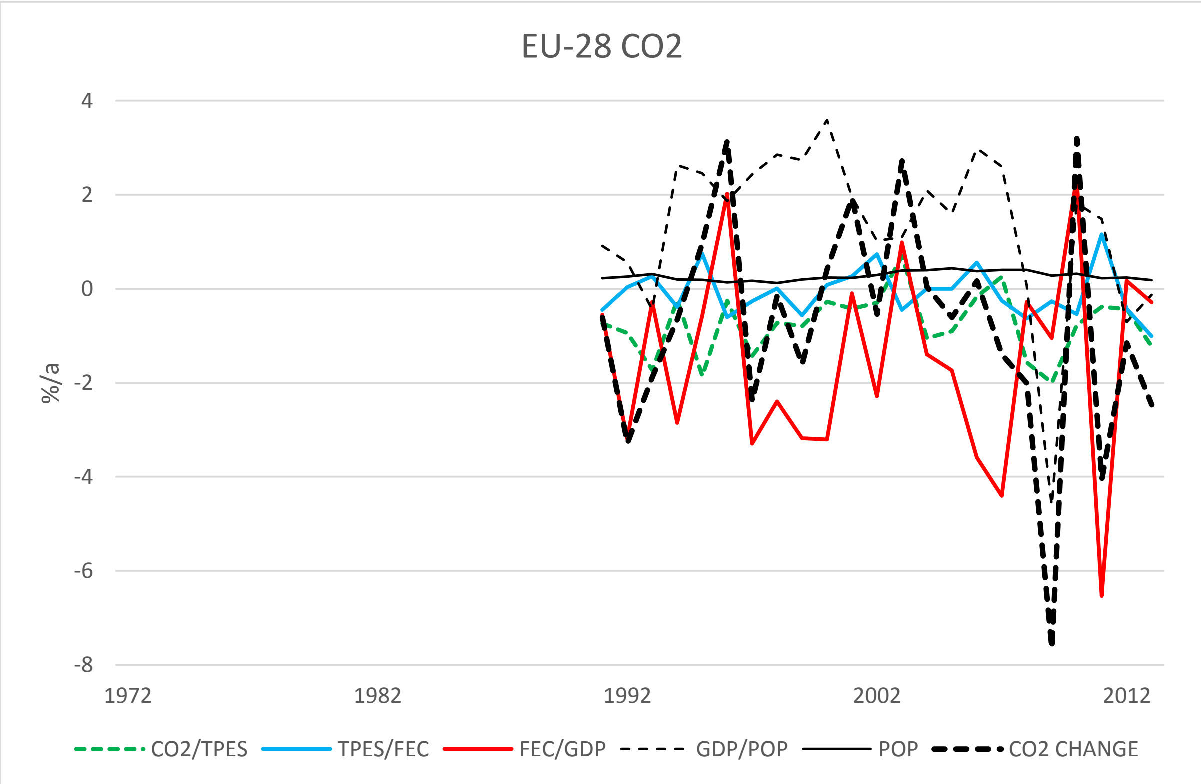
1972
1982
1992
2002
2012
TPES/FEC
FEC/GDP
GDP/POP
POP
TPES change


EU-28 CO2
%/a
4
2
0
-2
-4
-6
-8
1972
1982
1992
2002
2012
CO2/TPES
TPES/FEC
FEC/GDP
GDP/POP
POP
CO2 CHANGE