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The vital role of the target definition in the evaluation of a target

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ABSTRACT

This paper aims to conduct an ex-post evaluation of the EU 2020 primary energy savings target and determine, using decomposition analysis, the contribution of energy savings and efficiency policies toward target achievement. As the savings target has been defined as a 20% reduction relative to the 2020 projection in the reference scenario PRIMES-200, we argue that, for a correct evaluation, one should compare the 2020 projection with the realized energy use in 2020 rather than analyzing the period 2005 (the base year of the target) and 2020.

Our results show that reduced GDP growth (due to the economic recession of 2008-2012 and the COVID19 lockdown) is the main contributor to target achievement. The contribution of intensity and efficiency improvements is surprisingly low, despite the significant number of efficiency policies implemented since 2005. To a large extent, the intensity and efficiency improvements projected in PRIMES-2007, which did not materialize in reality, may explain this.

Our results suggest that using a reference scenario in the definition of a target becomes tricky if the reality of (mainly) economic growth deviates a lot from the projection and/or if the base year of the projection is an outlier. The latter issue may show up when evaluating the new 2030 energy savings target, which has been set relative to the 2030 projection of the PRIMES-2020 with COVID-year 2020 as the base year.

Introduction

Energy savings and efficiency improvement are among the key pillars for the deep decarbonization of society (IEA, 2021). Targets drive action towards improved efficiency or saving energy by putting a dot on the horizon and, as such, laying the ground for energy efficiency policy instruments and programs. The choice for a savings target emphasizes saving energy, whereas an efficiency target is steering efficiency improvement, leaving room for energy consumption to grow.

In 2007, the EU set three key 2020 targets: "20% cut in greenhouse gas emissions (from 1990 levels), 20% of EU energy from renewables, and 20% improvement in energy efficiency" (2020 climate & energy package (europa.eu)). In this paper, we focus on the third target. The European Commission explicitly labeled the target as an efficiency target on its website and in many other official EU documents (e.g., EC, 2020). However, it is truly a savings target finding its origin in the 2005 Green Paper on Energy Efficiency (Doing More With Less): "This Green Paper on energy efficiency envisages to launch the debate on how the EU could achieve a reduction of the energy consumption of the EU by 20% compared to the projections for 2020 on a cost effective basis." (EC, 2005). The projection used as the reference scenario for the target was the European Energy and Transport Trends to 2030 – Update 2007, hereafter PRIMES-2007 (Capros et al., 2008). Although many updates of the reference scenario have been published since then (Capros et al., 2010; Capros et al., 2014; Capros et al., 2016; Capros et al., 2021), the 2020 energy savings target has been defined as a percentage reduction (20%) relative to the 2020 projection of PRIMES-2007. This implies that the later reference scenarios were not relevant for the target *definition* but important to show to what extent the later projections converged to target achievement (a.o., through the impact of newly implemented efficiency policies).

The 20% energy savings target has often been redefined for communication purposes. The 2012 Energy Efficiency Directive (European Parliament & Council, 2012) and its progress reports (e.g., EC, 2020) translate the 20% target into an energy consumption cap for 2020, whereas, e.g., the European Environmental Agency redefines it as a percentage reduction of energy consumption compared to 2005 (e.g., EEA, 2020). See figure 1 for an overview.

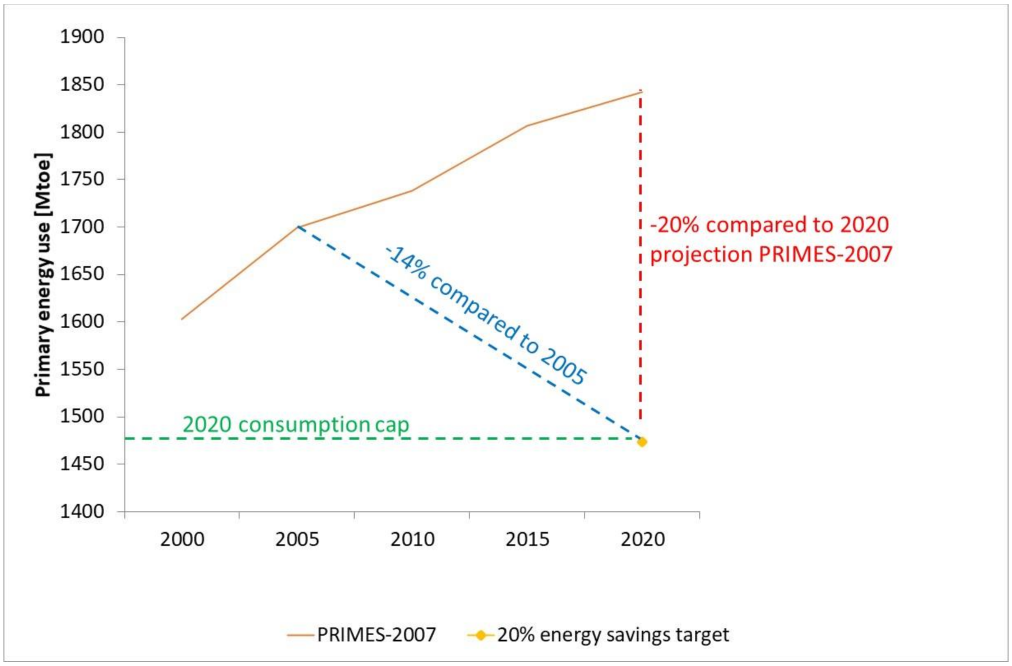

Figure 1. Three ways of defining the EU 2020 energy savings target

Based on 2019 energy consumption data, target achievement at the EU level was uncertain (EEA, 2020; EC, 2020). However, the EU overachieved its 2020 energy savings target (both in terms of primary and final energy) because of curbing transport activity and industrial production due to the COVID-19 lockdown (EEA, 2021).

This paper aims to conduct an ex-post evaluation of the 2020 energy savings target and determine, if possible, the contribution of energy savings and efficiency policies toward target achievement.

Approach

The original definition of the target plays a vital role in evaluating the target. It is not only energy savings and efficiency policies but also other effects that can contribute to or hamper target achievement. For example, lower economic growth than projected in PRIMES-2007 would contribute to target achievement, whereas a higher economic growth than projected would make target achievement more difficult. An advantage of the chosen definition is that progress toward target achievement can easily be derived from energy statistics, since it easily translated in a 2020 energy consumption gap. In contrast, the disadvantage for evaluators is the challenge to disentangle the policy contribution from the other effects. Using PRIMES-2007 as a reference scenario provides additional complexity to the evaluator. PRIMES-2007 includes a significant number of savings and efficiency policies or policies with energy efficiency relevance. To correctly evaluate the policy impact, the evaluator should find the policy impact *on top of* the effect of the policies embedded in PRIMES-2007. Table 1 shows the savings and efficiency policies in PRIMES-2007 and those implemented or strengthened afterward.

Table 1: Savings and efficiency policies in PRIMES-2007 and implemented/strengthened afterward

EE policies (or policies with EE relevance) in PRIMES-2007	Additional EE policies (or policies with EE relevance) that had an impact on 2020 energy use
SAVE Directive (1993)	Eco-Design Framework Directive (2005)
Building Directive (2002)	+ 29 Eco-Design Implementing Measures
Labelling Directive – household appliances (1992)	End-use Energy Efficiency and Energy Services Directive (2006)
Energy Star Program – office equipment (2003)	Energy Efficiency Directive (2012)
Directives on energy efficiency for boilers, refrigerators and ballasts for fluorescent lighting	Energy Performance of Buildings Directive (2010)
ETS Directive (2003/2004, €20/ton in Kyoto period)	Energy Labelling Directive (2010)
IPPC Directive (1996) / Large Combustion Plant Directive (2001)	IPPC Directive (2008) / Industrial Emissions Directive (2012)
CHP Directive (2004)	ETS Directive (2008/2009)
Energy Taxation Directive (2003)	Effort Sharing Decision (2009)
ACEA/KAMA/JAMA Agreement (1998/99)	Cohesion Policy – ERDF, ESF and Cohesion Fund
Car Labelling Directive (1999)	Regulation on CO_2 from cars (2009) and vans (2011)
	Labelling of Tyres Regulation (2011)
	Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles (in public procurement) (2009)
	Directive establishing a single European railway area (Recast, 2010)
	IMO Resolution Inclusion of regulations on energy efficiency for ships
	Directive on Alternative Fuels Infrastructure (2014)

Source: Carpos et al. (2008), Capros et al. (2010), Capros et al. (2014), Capros et al. (2016)

The above implies that analyzing the contribution of driving factors to the observed development of energy consumption between 2005 and 2020 cannot be considered an evaluation of the 2020 energy savings target since such an approach bypasses PRIMES-2007. The intensity or efficiency effect found when decomposing the change of energy use between 2005 and 2020 is the combined net effect of, a.o., pre-PRIMES-2007 policies, autonomous efficiency improvement, and the after-PRIMES-2007 policies.

Román-Collado and Economidou (2021), who used decomposition analysis to study the development of EU energy consumption between 2000 and 2018, highlight the contributions of the economic recession (2008-2012) and the COVID-19 lockdown to the 2020 target achievement but consider this a limitation of the EU savings target as it is set against PRIMES-2007. We agree with that. However, to overcome this limitation, this paper uses a different decomposition approach that allows quantifying the contributions. Rather than analyzing 2005-2020 alone (with 2005 being the base year of PRIMES-2007), the first step in our analysis, we also focus on the difference between the 2020 PRIMES-2007 projection and the 2020 energy consumption reported by Eurostat to show the different contributions of the driving factors compared to the 2005-2020 analysis. Smit et al. (2014) were the first to make the 2020 comparison to evaluate ex-ante the EU's energy savings target.

We start our analysis with the following economy-wide decomposition identity, using GDP as the activity indicator, FE/GDP as the economy-wide intensity indicator, and PE/FE as the (inverse of the) economy-wide efficiency[1]:

$$PE = GDP \times \frac{FE}{GDP} \times \frac{PE}{FE} \quad (1)$$

With: PE = primary energy consumption; FE = final energy consumption; GDP = gross domestic product.

Using Log Mean Divisia decomposition analysis (Ang, 2004), we first analyze the period 2005-2020 with the following formulas:

$$volume\ effect = LM \times \ln \frac{GDP_{2020}}{GDP_{2005}} \quad (2)$$

$$intensity\ effect = LM \times \ln \frac{(FE/_{GDP})2020}{(FE/_{GDP})2005} \quad (3)$$

$$efficiency\ effect = LM \times \ln \frac{(PE/_{FE})2020}{(PE/_{FE})2005} \quad (4)$$

With $LM = \frac{PE_{2020} - PE_{2005}}{ln\frac{PE_{2020}}{PE_{2005}}}$ (5)

Similarly, we analyze the difference between 2020 energy use (Eurostat vs. PRIMES-2007) with the following formulas:

$$volume\ effect = LM \times \ln \frac{GDP_{2020Eurostat}}{GDP_{2020PRIMES2007}} \quad (6)$$

$$intensity\ effect = LM \times \ln \frac{FE/_{GDP}2020Eurostat}{FE/_{GDP}2020PRIMES2007} \quad (7)$$

$$efficiency\ effect = LM \times \ln \frac{PE/_{FE}2020Eurostat}{PE/_{FE}2020PRIMES2007} \quad (8)$$

With $LM = \frac{PE_{2020Eurostat} - PE_{2020PRIMES2007}}{\ln\frac{PE_{2020Eurostat}}{PE_{2020PRIMES2007}}}$ (9)

By discussing the different outcomes between the two approaches, we will argue that by analyzing the difference *between 2020 energy use*, the second approach is the most appropriate for evaluating the EU energy savings target.

After the economy-wide analysis, we have an in-depth look into the power & heat sector (power-only plants and combined heat & power plants), the industry & services sectors, and the residential sector. For these, we only analyze the difference between 2020 energy use. The decomposition identities we use are the following:

Power & heat sector: $PE = \sum_i (G + 0.2 \times H) \times \frac{(G+0.2\times H)_i}{(G+0.2\times H)} \times \frac{PE_i}{(G+0.2\times H)_i}$ (10)

[1] Note that this efficiency is the efficiency of the transformation sector (power plants, district heating, refineries etc.). End-use efficiencies (e.g., the efficiency of domestic boilers) cannot be derived from energy statistics since it is the fuel delivered to the end-used which is shown, not the heat produced with it.

With: G = electricity generation; H = useful heat production; i = fuel category (thermal power or 100% RES, i.e., PV, wind, hydro). The factor 0.2 is the power-loss factor and resembles that useful heat production in a combined heat & power plant goes at the expense of the plant's electricity generation. The first driving factor is the volume effect, the second is the structure effect (share of thermal or 100% RES technologies in total generation), and the third is the efficiency effect.

Industry and services sectors: $FE = \sum_i SVA \times \frac{SVA_i}{SVA} \times \frac{FE_i}{SVA_i}$ (11)

With: SVA = Sector value added; i = subsector (industry or services).

Residential sector: $FE = POP \times \frac{HH}{POP} \times \frac{FE}{HH}$ (12)

With: POP = population; HH = households.

The set-up of the Log Mean Divisia formulas linked to identities 10-12 follows the structure of formulas 6-9.

Our data sources were PRIMES-2007 (Capros et al., 2007) and Eurostat (Home - Eurostat (europa.eu)). Since PRIMES-2007 does not include a projection for Croatia and the UK is not EU anymore, our analysis focused on the EU26. Within the scope of this paper, we did not provide results for the individual Member States. This limits the results to a certain extent since all effects shown are *net* effects at the EU26 level, possibly hiding member state-specific effects that move in a different direction. Regarding the end-use sectors, we did not include the transport sector (passenger and freight) as Eurostat 2020 data is still incomplete for several member states at the moment of writing this paper.

Although the 2020 energy savings target was initially based on primary energy (EC, 2005), in the 2012 Energy Efficiency Directive (European Parliament & Council, 2012), it was left to the Member States whether to set a primary or a final energy savings target. The main advantage of a final energy savings target was the reduced interaction between national efficiency policies and the EU ETS, which, as of phase III, had become an EU-wide instrument. For the purpose of this paper, i.e., showing the vital role of the target definition in its evaluation, we focus on evaluating the primary energy savings target only.

Results

Economy-wide analysis 2005-2020

Figure 2 shows the decomposition results of the economy-wide analysis of the EU based on 2005 and 2020 data from Eurostat Statistics. The volume effect leads to an increase in primary energy use. This is well explained by the rise in GDP in this period, see Figure 3, *despite the economic recession and the COVID-19 lockdown*.

At the same time, the intensity (FE/GDP) and efficiency (PE/FE) effects lead to a decrease in primary energy use. This is the combined effect of pre-PRIMES-2007 policies, autonomous efficiency improvement, and after-PRIMES-2007 policies. The decomposition of energy use with the data sources used in the analysis does not allow for analyzing the effects separately. Still, figure 2 at least suggests that the contribution of policies to target achievement (intensity and efficiency improvement) is significant. The efficiency improvement seems small, e.g., knowing that 100% RES technologies (wind, solar) grew significantly between 2005 and 2020. However, figure 2 shows the economy-wide results. The effect of solar and wind electricity growth on primary energy savings is better shown when analyzing the power & heat sector in detail (see later).

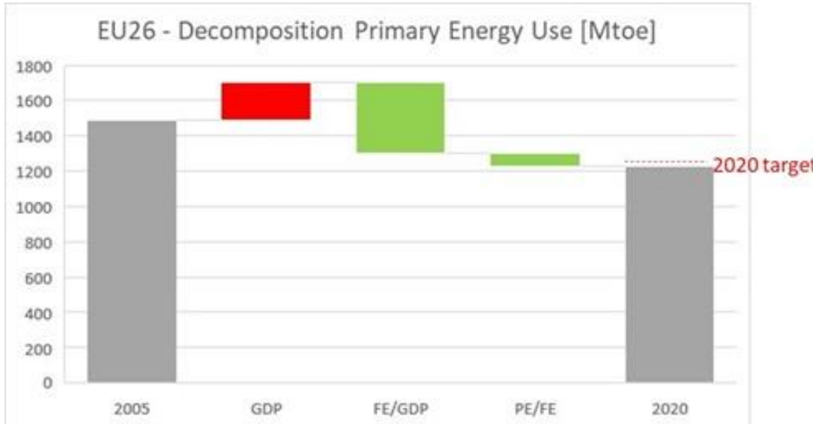

Figure 2. Contribution of the driving factors to the change in the economy-wide primary energy use 2005-2020.

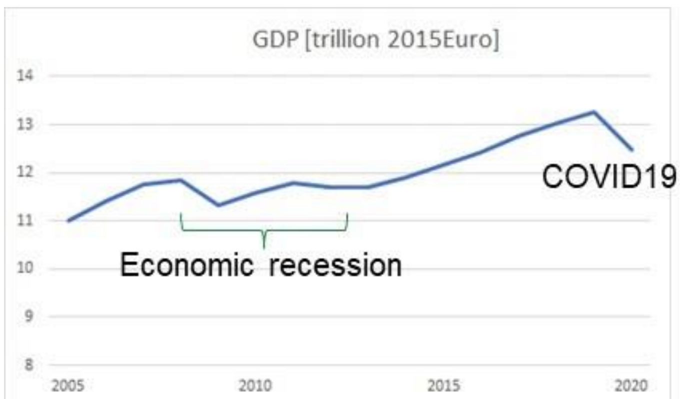

Figure 3. GDP development in the EU26. *Source:* Eurostat.

Economy-wide analysis $2020_{Eurostat}$-$2020_{Primes-2007}$

Figure 4 shows the decomposition results of the economy-wide analysis when comparing the 2020 primary energy use between Eurostat and PRIMES-2007. Unlike figure 2, the volume effect contributes to a reduction in energy consumption. The explanation is a higher projected growth of GDP in PRIMES-2007 compared to actual developments, the latter affected by the economic recession and the COVID-19 lockdown (Figure 3). The intensity effect (FE/GDP) in Figure 4 is smaller than in Figure 2. However, it still reduces primary energy use on top of the intensity improvement in PRIMES-2007. This could be explained as an impact of after-PRIMES-2007 savings and efficiency policies when we assume that the effects of pre-PRIMES 2007 policies and autonomous efficiency improvement are canceled out. At this aggregation level, it is difficult to assess if this is a correct assumption. An in-depth look into the power & heat sector, the industry and services sectors, and the residential sector may reveal this (see later).

Figure 4 also shows that the efficiency effect (PE/FE) marginally leads to increased primary energy use. This means the economy-wide efficiency in 2020 was lower than the projected efficiency in PRIMES-2007. This is an unexpected result given the long list of after-PRIMES-2007 policies (see Table 1). In the following sections, we will attempt to explain this effect by looking into the power & heat sector, the industry and services sectors, and the residential sector.

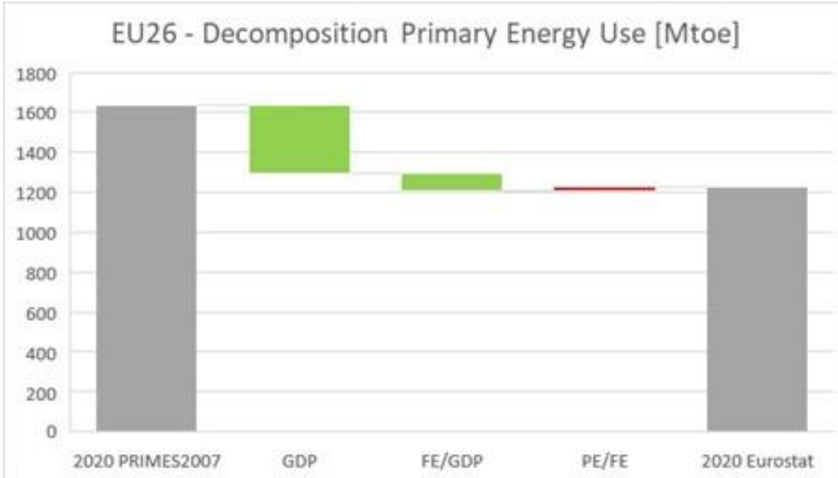

Figure 4. Contribution of the driving factors to the difference in the economy-wide 2020 primary energy use

Power & heat sector analysis $2020_{Eurostat}$-$2020_{Primes-2007}$

Figure 5 shows the decomposition analysis of the power & heat sector (power only and combined heat & power plants). The volume effect contributes to a reduction in primary energy use. The explanation is the lower electricity (and heat) generation in 2020 compared to the PRIMES-2007 projection. The fuel mix effects in the figure mimic the net effect of the intensified renewable energy policies on primary energy savings. The additional growth of so-called 100% renewables (i.e., renewables with a default conversion efficiency of 100% in Eurostat energy statistics: PV, wind, hydro) compared to the PRIMES-2007 projection leads to an increase in primary energy use of +37 Mtoe. However, this increase in energy use is more than compensated by a decrease in primary energy use by thermal power production (-106.4 Mtoe). The combined effect is the net contribution of renewable energy policies to the EU's energy savings target. Although a policy effect, it cannot be considered a savings or efficiency policy effect. Harmsen et al. (2011) referred to this as "the unrecognized contribution of renewable energy to Europe's savings target".

Figure 5 does not show an efficiency effect for the 100% RES technologies. If efficiency does not change (in this case: it remains 100%), its contribution to explaining the difference in energy use is zero. Mathematically:

$LM \times \ln(x/x) = LM \times \ln(1) = 0$ since $\ln(1)=0$.

The efficiency effect of thermal power (+94.8 Mtoe) is unexpected. It implies that the efficiency improvement in the PRIMES-2007 projection was more significant than the actual improvement. This may partly be explained by the reduced need for new fossil power plants (with high efficiencies) because of the growth of especially wind and solar, i.e., the projected efficiency improvement in PRIMES-2007 simply did not materialize. However, it also seems that the assumptions regarding fossil power efficiency improvement in PRIMES-2007 were too optimistic (Smit et al., 2014).

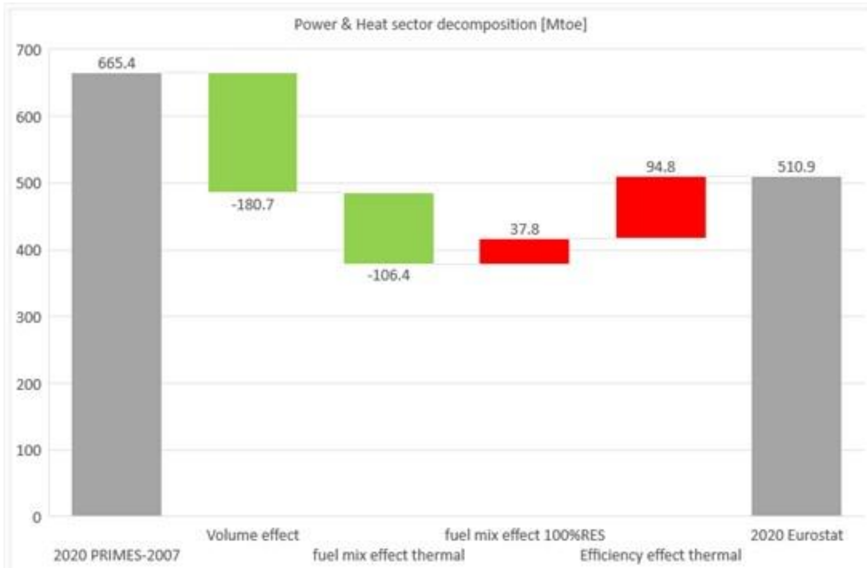

Figure 5. Contribution driving factors to the difference in 2020 primary energy use in the power & heat sector

Industry and Services analysis $2020_{Eurostat}$-$2020_{Primes\text{-}2007}$

The decomposition analysis of the industry and services sector is shown in Figure 6. As the figure shows, the volume effects reduce final energy use for the industry and services sectors. The slower growth of sector value-added compared to the PRIMES-2007 projection explains this.

Figure 6 shows a structure effect of -12 Mtoe. This mimics a shift from industry to services, the latter being the more efficient sector in terms of final energy use per unit of sector value-added. The intensity effect (FE/SVA) in the industry and services sectors leads to an increase in final energy use. This does not mean that intensity did not improve in the sectors. However, the improvement was slower than in the PRIMES-2007 projection. This outcome is remarkable given the intensification of energy efficiency policies in both sectors. It may partly be explained by using a monetary activity indicator (SVA), which is not the best indicator for measuring energy efficiency policy impact (e.g., Román-Collado and Economidou, 2021). Since PRIMES-2007 does not report the underlying physical activity indicators (tons of industrial output, number of employees, m^2 office area, etc.) used in the modeling, using physical activity indicators for the evaluation of the 2020 energy savings target is not possible.

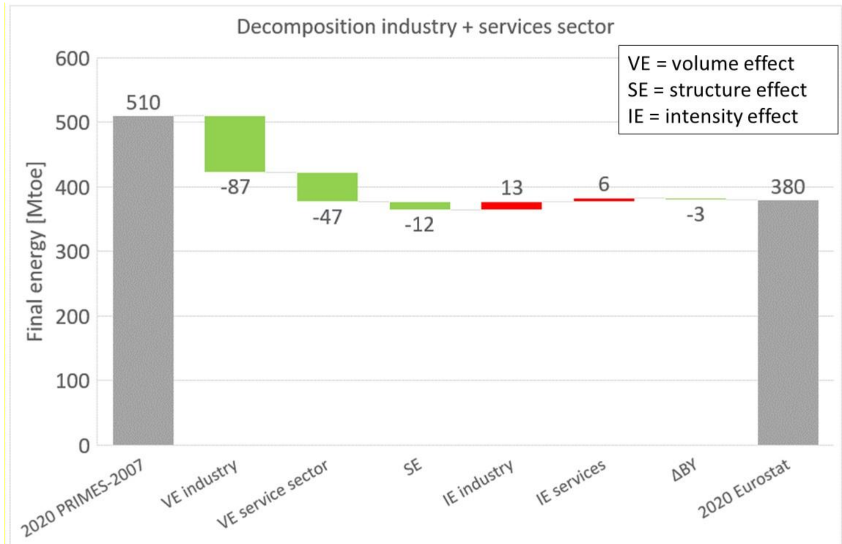

Figure 6. Contribution of the driving factors to the difference in 2020 primary energy use in the industry and services sectors (ΔBY refers to a slight difference in the 2005 final energy consumption between Eurostat and PRIMES-2007)

Residential sector analysis $2020_{Eurostat}$-$2020_{Primes-2007}$

The decomposition analysis of the residential sector shown in figure 7 is relatively straightforward. At the EU level, the differences in the 2020 population and household density compared to the PRIMES-2007 projections are relatively small. At the same time, the efficiency effect (final energy per household) leads to a significant decrease in energy consumption (-53 Mtoe). This aligns with the strengthened building policies, the increased focus on retrofitting the existing building stock, and the new (after-PRIMES-2007) policies targeting household appliances' energy efficiency.

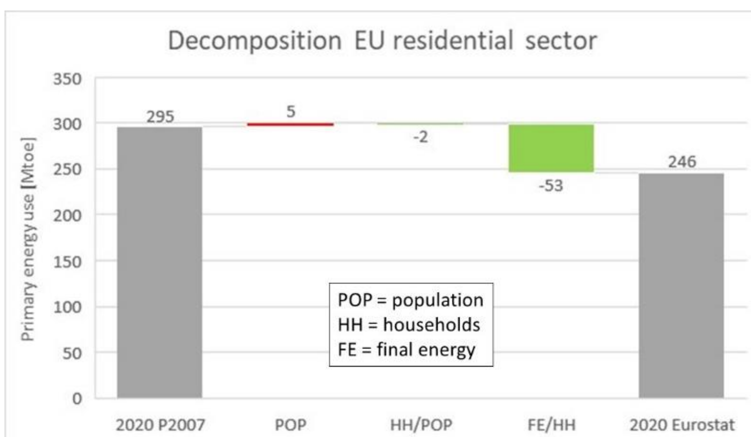

Figure 7. Contribution of the driving factors to the difference in 2020 primary energy use in the residential sector

Conclusions

The EU overachieved its 2020 energy savings target in terms of primary and final energy. For years, this was not expected. Progress reports from the European Commission, the European Environmental Agency, and several scientific papers stressed the likelihood of missing the target for years.

We have shown, only looking at the primary energy savings target, that for correctly evaluating the EU 2020 energy savings target, one should analyze the difference between the 2020 energy use in the PRIMES-2007 projection and Eurostat. Although studying the period 2005-2020 provides valuable insights, it is not the way to evaluate the energy savings target. The decomposition results of 2005-2020 themselves give a clue: GDP is growing and leads to an increase in primary energy use between 2005 and 2020. However, it is clearcut that the savings target was achieved because of the combined result of the economic recession (i.e., its remaining impact) and the more recent COVID-19 lockdown, i.e., lower economic growth than projected in PRIMES-2007.

Although energy efficiency improved between 2005-2020, our economy-wide analysis suggests that the contribution of new or strengthened energy savings and efficiencies policies was marginal or even contra-productive (leading to more primary energy use). This is obviously not true. However, explaining this requires insight into the model assumptions used in PRIMES-2007. This insight is lacking and hampers the detailed evaluation of the energy savings target which is wished for (i.e., isolating the policy impact from the impact of, e.g., model assumptions or policy impacts in PRIMES-2007 that did not materialize in reality).

Diving deeper into the sectors, we found that the projected energy efficiency improvement in the industry and the services sector in the PRIMES-2007 reference scenario was more significant than the actual improvement. This may be explained by reduced investment in new and more efficient production processes and appliances (less growth, less need for capital goods) but can also be due to too optimistic assumptions in the reference scenario. Also, in the power & heat sector, the thermal efficiency improvement in the reference scenario was much bigger than the actual development (again, partly explained by reduced investments in new efficient thermal capacity, partly by optimistic assumptions in PRIMES-2007). However, this effect was primarily counterbalanced by the massive amount of "artificial" energy savings from wind and solar that increased significantly compared to the PRIMES-2007 projection for meeting the 2020 renewable energy target. This interaction with the renewable energy target can be avoided when only considering a final energy savings target.

The residential sector was the only sector in our analysis with an apparent efficiency effect. It is, therefore, the only sector where the new and strengthened savings and efficiency policies convincingly contribute to target achievement without being hidden by other effects.

If a target is set against a reference scenario, this scenario should be used for evaluating it. Evaluating the target and bypassing the underlying reference scenario overestimates the policy impact as it includes the effect of policies already embedded in the reference scenario (compare our Figures 2 and 4).

The risk of setting a target against a reference scenario is that reference scenarios may rapidly be outdated. This was the case with PRIMES-2007, which was outdated when the recession hit the world in 2008. If reality deviates too much from a projection, the analysis becomes blurred. With this insight, it was surprising to learn that for "consistency" reasons, the European Commission also defined the new 2030 energy savings target against the PRIMES-2007 reference scenario (draft recast of the Energy Efficiency Directive). The strongly deviating GDP figures from a long time ago would still be playing a role in the (correct) target evaluation of 2030. In the meantime, the Commission has redefined the target and now used the 2020 Reference scenario (EC, 2021). As 2020 energy use (the base year of the scenario) has been strongly affected by COVID19, it may be questioned whether using this scenario is a better alternative (to what extent are the 2030 projections affected by the “shaky” 2020 base year?). With a headline GHG reduction target (for the EU, -55% in 2030 compared to 1990), which is already prone to fluctuations in the economy, the supporting energy sub-target might be better formulated as a true efficiency target to maintain a focus on making the energy system future-proof.

References

Ang, B. 2004. Decomposition analysis for policymaking in energy, *Energy Policy*, 32 (9), pp. 1131-1139.

Capros, P., Mantzos, L., Papandreou, V., Tasios, N. 2008. European Energy and Transport, Trends to 2030 - Update 2007. ICIS-NTUA, Athens, Greece. Report for the European Commission.

Capros, P., Mantzos, L., Tasios, N., De Vita, A., Kouvaritakis, N. 2010. EU Energy Trends to 2030 – update 2009. ICIS-NTUA, Athens, Greece. Report for the European Commission.

Capros P., De Vita A., Tasios N., Papadopoulos D., Siskos P., Apostolaki E., Zampara M., Paroussos L., Fragiadakis K., Kouvaritakis N., 2013. EU Energy, Transport and GHG emissions-Trends to 2050 - Reference scenario 2013. Report for the European Commission.

Capros, P., De Vita, A., Tasios, N., Siskos, P., Kannavou, M., Petropoulos, A., Evangelopoulou, S., Zampara, M., Papadopoulos, D., Nakos, Ch. 2016. EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050. Report for the European Commission.

Capros P., De Vita A., Florou, A. 2021. EU Reference Scenario 2020 - Energy, transport and GHG emissions - Trends to 2050. Report for the European Commission.

EEA (European Environmental Agency) 2020. Trends and projections in Europe 2020.

EEA 2021. Trends and projections in Europe 2021.

EC (European Commission) 2020. 2020 climate & energy package (europa.eu).

EC 2005. Green Paper on Energy Efficiency or Doing More With Less, COM(2005) 265 final.

EC 2020. 2019 assessment of the progress made by Member States towards the national energy efficiency targets for 2020 and towards the implementation of the Energy Efficiency Directive as required by Article 24(3) of the Energy Efficiency Directive 2012/27/EU, COM(2020) 326 final.

EC 2021. Proposal for a recast of the Energy Efficiency Directive. COM(2021) 558 final.

European Parliament & Council 2012. Energy Efficiency Directive 2012/27/EU.

Eurostat Statistics, Home - Eurostat (europa.eu).

Harmsen, R., Eichhammer, W., Wesselink, B., Worrell, E. 2011. The unrecognized contribution of renewable energy to Europe's savings target, *Energy Policy*, volume 39, issue 6, pp. 3425 – 3433.

IEA (International Energy Agency) 2021. Net Zero by 2050: A Roadmap for the Global Energy Sector.

Román-Collado, R. and Economidou, M. 2021. The role of energy efficiency in assessing the progress towards the EU energy efficiency targets of 2020: Evidence from the European productive sectors, *Energy Policy*, volume 156, 112441.

Smit, T., Hu, J., Harmsen, R. 2014. Unravelling projected energy savings in 2020 of EU Member States using decomposition analyses, *Energy Policy*, volume 74.