Ex post evaluation and policy implementation in the European building sector

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ABSTRACT

This paper focuses on the ex post evaluation of national energy efficiency policy mixes in the building sector, more specifically the effectiveness of implemented policy packages on helping to achieve energy savings and avoided greenhouse gas emissions (GHGs). The analysis covers all Policies and Measures (PaMs) affecting heating and cooling of residential buildings. Main research questions are: Is there a relationship between improvements in energy efficiency and GHG mitigation and the PaM history set-up within a Member State (MS)? Which are the driving factors behind the latest energy consumption trends? Hereto, the analysis starts from a literature review on effectiveness of implemented PaMs for the building sector. Afterwards, six Member States, namely France, the Netherlands, Czech Republic, Cyprus, Sweden and Bulgaria, are assessed in more detail. The detailed assessment includes gathering of existing PaMs as implemented in the six cases, and an index decomposition analysis (IDA) of CO_2 emissions. The IDA of CO_2 is applied to evaluate whether the different policy packages in different cases are effective on reducing energy consumption and mitigating CO_2 in the residential sector. Hence, the approach followed in this paper will enable the correlation between currently adopted policy packages and quantified CO_2 savings, providing a consistent approach to assess how effective MS policies are on reaching energy efficiency and climate goals. The paper brings together two recent assessments in frame of the European Topic Centre for Air Pollution and Climate Change Mitigation under the authority of the European Environment Agency.

Introduction

Buildings account for about 40 % of total final energy consumption and around 60 % of electricity consumption in the EU-28 in 2015. This makes buildings the largest energy end-use sector, followed by transport (33%), industry (25%) and agriculture (2%). In some countries, such as Estonia, Croatia and Hungary, buildings represent more than 45% of final energy consumption in countries (Eurostat, 2017). For the EU-28 as a whole, around two thirds of the energy consumption of buildings is in the residential sector (Odyssee-MURE, 2015). Therefore, the reduction of energy consumption and the increased use of energy from renewable sources in buildings constitute important measures needed to reduce the Union's energy dependency and greenhouse gas emissions.

The current core Union policies aimed at reducing energy consumption in buildings are the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED), and several product regulations laying down minimum energy performance standards and putting energy performance information on labels (Ecodesign and Energy Labelling) (EC, 2016). On 30 November 2016 the European Commission presented a new package of measures to keep the European Union competitive as the clean energy transition changes global energy markets, in the so-called 'winter package'. The 'winter package' recognizes that the building stock still provides a large potential for energy savings. This includes both new and existing buildings, although the tighter minimum energy performance requirements and the high compliance rates of new buildings (typically above 80 %), means that the largest saving potential remains mostly in the existing buildings stock (EC, 2016).

This explains why many studies have a forward looking perspective, with recommendations for future policy developments. However, a retrospective perspective is also needed to understand if and to which degree policies have contributed to energy efficiency in buildings. Moreover, while studies on single instruments are valuable, it is important to consider the wider context in which instruments are designed and implemented (Kern et al., 2017). In the building sector, energy efficiency improvements are hindered by various barriers, among which legal and regulatory barriers, financial barriers like split-incentives, information deficits, organizational barriers such as need for collective decisions in apartment blocks. Each of these barriers needs to be addressed by different types of measures. It is often cited in literature, that developing a balanced policy mix which includes several types of measures is required for effective energy efficiency policies. Moreover, these measures target several sectors or end-users and may be implemented at different stages of the development.

Therefore, in this paper we attempt to contribute to the debate on the impact of policy mix design on effectiveness of energy efficiency PaMs by linking an ex post qualitative assessment of PaMs in six countries with a CO_2 index decomposition analysis (IDA) in order to assess whether different sets of PaMs in these countries have been effective in contributing to CO_2 mitigation.

Literature review about policy implementation linked to effectiveness

Odyssee-MURE (2015) and the EPBD evaluation (2016) show that the actual energy efficiency for the energy uses of heating and cooling has improved since 2000 at the EU level in the household sector as well as in the services sector. Concerning the residential sector, this is mainly linked to the energy efficiency improvement for space heating and electrical appliances. Although after 2006, the application date of the EPBD, a clear positive change of trends in the EPBD is observed in the household sector, the economic downturn had a clear impact.

As the EEA PaM and MURE database (EEA, 2017a,and Odyssee-MURE, 2017) show that some Member States have already a long tradition in energy efficiency policies in buildings, PaMs have been superseded, revised and strengthened throughout the years. An important step was the introduction of the EPBD in 2002 having far-reaching impact on owners, operators and developers of all buildings. Hence, there is an overall increasing trend of the number of PaMs that have been implemented. Studies, like EC (2016), show that in the recent decade national energy efficiency policies have increasingly been influenced by Union policies, like the recast of the EBPD, Energy Services Directive and the EED. Besides EU legislation, also the promotion of Energy Services Companies (ESCOs) by multiple EU and international institutions, like the European Investment Bank, influence the professional landscape of energy efficiency in buildings (World Energy Council, 2016).

Econometric and panel data studies exploit the observed heterogeneity in policies in order to investigate how policies and energy prices – including energy taxes – have influenced energy efficiency, together with other determining factors such as household income, population, heating degree days, etc (VITO, 2017). Several studies showed that energy efficiency policy can be a strong driver of energy efficiency improvements in the EU. For example Bertoldi and Mosconi (2015) found that, in the absence of energy policies, energy consumption in EU-28 countries and Norway would have been approximately 11% higher in 2013. Filippini et al. (2014) found that financial measures have the highest impact on energy efficiency. Information measures, which contain labelling, surprisingly lead to less energy efficiency. Among the regulatory measures, the performance standards of buildings, heating systems and appliances have a positive effect on energy efficiency, but less so than financial measures. The authors refer to the longer penetration time of the regulations as they apply to new buildings. Broin et al. (2015) found that regulatory policies have an immediate impact from the first year of implementation onwards. This type of measures is found to have a consistent impact over the years. Financial policies only have a small impact in the year of introduction and require a number of years before having a significant impact.

Apart from policies, there can be other explanations that drive energy efficiency improvements. These autonomous trends are energy efficiency improvements that occur because of - for instance - technological improvements that are driven by inherent economic processes, increasing energy prices etc. On top, panel data studies indicate that although financial incentives (private or public) and subsidies have a positive impact on the probability to undertake energy efficiency improvements, the presence of free-riding turns out to be a problem: a significant number of people would have undertaken the energy efficiency upgrading measures anyway, even without the incentives (VITO, 2017). These analyses make it clear that it is difficult to get a transparent view on the causal relationship between energy efficiency and the implemented individual policy instruments nor the policy mix as a whole within Member States.

Methodology

In this paper, a partial ex post evaluation of energy efficiency policies and measures (PaMs) in residential buildings focusing on heating and cooling is performed. In this analysis, a building is defined as a roofed construction having walls, for which energy is used to condition the indoor climate in the households sector. This means that all PaMs improving the energy efficiency of heating and cooling in residential buildings (including sanitary hot water) are considered. Considering that Union policies improving energy efficiency in buildings are important, the considered PaMs will mainly be linked to the Union policies EBPD, EED, and - to a lesser extent – the Ecodesign and Energy Labelling Directives.

In this paper, following three questions linked to the evaluation of effectiveness and coherence of PaMs are considered:

- Implementation status:
  Which policies have Member States implemented to improve energy efficiency in buildings?
- Effectiveness & Coherence:
  Has policy intervention resulted in energy efficiency improvements?
  How is the relationship between improvements in energy efficiency and the national policies within a Member State? Is the level of coherence of national policy mixes for energy efficiency in buildings linked to the evolution of energy efficiency?

The ex post evaluation of national energy efficiency policy mixes is focused on the coherence and effectiveness of implemented policy packages. In the evaluation of coherence, a distinction is made between external (to what extent is the intervention coherent with other interventions) and internal (to what extent is the intervention coherent internally) coherence. As the evaluation comprises a set of different individual instruments to improve buildings' energy efficiency, coherence is limited to the internal coherence of the set of instruments e.g. how different energy efficiency policy instruments interact with one another and how these policy instruments address different barriers and actors. It does not cover external coherence with Union policies or with policies with an objective outside the scope of the analysis.

As indicated above, one part of the effectiveness assessment look closer to the actual implementation within the member states (implementation status), while the last two questions evaluate the relationship between objectives and outputs of the national policy mixes (i.e. in this context, improvement of energy efficiency via energy intensity increase).

The analysis consists of a detailed and comprehensive analysis of six case studies of Member States' policy mixes, to verify and complete the guiding principles of designing a coherent and effective policy mix to improve the energy efficiency of buildings. The six case studies are: Sweden, Czech Republic, France, the Netherlands, Bulgaria and Cyprus, representing a variation of climate zones and policy types.

The paper brings together two recent assessments in frame of the European Topic Centre for Air Pollution and Climate Change Mitigation under the authority of the European Environment Agency (EEA, 2018 and EEA, to be published).

Overview of PaMs in the six case studies

For the assessment of policy instruments in the case studies incentivizing energy efficiency in buildings, the review primarily relies on information provided by the Member State through:

- the updated fourth National Energy Efficiency Action Plan (NEEAP) submitted in 2017;
- the MURE database (http://www.measures-odyssee-mure.eu/) and
- under the Monitoring Mechanism Regulation (MMR), which is collected in the EEA PaM database (EEA, 2017a, http://pam.apps.eea.europa.eu/).

To this end, an excel file was compiled to collect relevant information on national energy efficiency policies from the different case studies. This excel file was shared with Member States to check for completeness and accuracy and to ask for any additional national information that could be relevant.

While the above sources provide the most up to date information on climate policies in Member States, issues regarding data availability limit the scope of any undertaken assessment. Consequently, a full in-depth assessment of policy coherence and their compatibility is outside the scope of this assessment. Instead, this study aims to provide a basic assessment of instruments in the different countries aimed to promote energy efficiency, discussing the current state of energy efficiency in the country, and the need for additional policy evaluation.

CO_2 Index Decomposition Analysis of Six Case Studies

In order to quantify the effectiveness of policy mixes, a CO_2 index decomposition analysis (IDA) was conducted for the residential sector in the six countries and compared with a decomposition for the EU28 region for the period between 2005 and 2015. The IDA is aligned with the energy IDA developed by the European Commission (EC, 2017) and, when relevant, its results are also considered.

The main idea underlying the IDA methodology is to quantify the impact, e.g., relative contributions of pre-determined factors on an indicator (so-called "aggregate") of interest (Ang & Liu 2001). In this context, the 'energy efficiency' effect, reflected as a reduction or increase in the energy intensity, can be isolated from other factors that also impact energy consumption or GHG emissions (IEA 2014). For the purpose of this study, five factors are taken into account (IEA, 2016; Xu and Ang, 2013; EC, 2017):

- Activity: accounts for change in CO_2 emissions due to changes in economic activity. In this sense, it is positive if the economic indicator growths due to increased energy demand[1];
- Intensity: accounts for changes in emissions due to technology advancements, efficiency improvements, policy and any other effects that would impact energy intensity;
- Fuel Mix: accounts for changes in the CO_2 emissions due to changes in the mix of fuels consumed;
- Emission Coefficient: considers changes in the carbon content of fuels consumed. In this study, emission coefficients of fossil fuels are considered to be constant over time, so the impact of this factor is derived from the evolution of carbon content of electricity due to changes of the power generation mix in each country;
- Weather: it captures changes to energy consumption due to weather changes and it is based on heating degree days per period.

There are different IDA methods available for tracking progress on GHG emissions. In this paper, we use the multiplicative LDMI I method because it is perfect in aggregation, e.g., it leaves no residual value in its calculation, with a still simple mathematical formulation (Ang 2015). The formulation of the multiplicative LDMI I method is based in the CO_2 emissions between two periods of interest which results from a governing function:

$$R = \frac{C_{t_2}}{C_{t_1}} = R_{act}.R_{int}.R_{fuel}.R_{EF}.R_W$$

(Equation 1)

Where:

R: Relative GHG emissions variation between the specified periods (t_1 and t_2) in the considered country/region;

C_{t1}: GHG emissions in period t_1 in the considered country/region;

C_{t2}: GHG emissions in period t_2 in the considered country/region;

[1] In this paper, the gross domestic product is chosen as activity indicator as energy consumption is not split into different services (such as heating) and due to the completeness of the dataset in the literature.

R_{act}: Relative GHG emissions variation between t_1 and t_2 due to the activity effect in the considered country/region;
R_{int}: Relative GHG emissions variation between t_1 and t_2 due to the intensity effect in the considered country/region;
R_{fuel}: Relative GHG emissions variation between t_1 and t_2 due to the fuel mix effect in the considered country/region;
R_{EF}: Relative GHG emissions variation between t_1 and t_2 due to the emission coefficient effect in the considered country/region;
R_W: Relative GHG emissions variation between t_1 and t_2 due to the weather effect in the considered country/region;

In that context, the factor R_{int} will indicate the amount of CO_2 emissions mitigated due to energy efficiency improvements thanks to energy efficiency policies with a direct impact on the carbon intensity of the residential sectors.

The CO_2 emissions IDA decomposition used the Eurostat Database and the European Commission energy IDA report (EC, 2017) as references for input data. Table 1 below shows the indicators used for each factor within the IDA method and states from where input data has been collected. Moreover, Annex A from this paper details the LDMI I decomposition calculation adopted.

Table 1. Description of indicators used in the IDA Decomposition.

IDA Factor	Indicator	Data
Activity	GDP	EC (2017)
Intensity	FEC'/GDP	EUROSTAT (nrg_sankey - B102010) & EC (2017)
Fuel Mix	$F_{ij,t}/F_{i,t}$	EUROSTAT (nrg_sankey - B102010) & EC (2017)
Emission Coefficient	$EC_{ij,t}$	Annex VI of Commission Regulation 601/2012 MMR and EEA (2017)
Weather	HDD/HDD_{ref}	EC (2017)

Where:
GDP: gross domestic product; FEC': HDD adjusted final energy consumption; $F_{ij,t}$: final energy consumption of fuel 'j' in sector 'i' and period 't'; $EC_{ij,t}$: CO_2 emission coefficient of fuel 'j' in sector 'i' and period 't'; HDD: heating degree days of period 't'; HDD_{ref}: heating degree days of the reference period 1990-2015.

As can be seen, the input data covers activity and energy consumption data for the whole residential sector. Moreover, the final energy consumption was duly adjusted for weather in order to account for different weather in different periods impacting the variation of energy consumption for heating. This was made by dividing the final energy consumption with the ratio 'HDD/HDD_{ref}' provided in EC (2017).

Assessment and Results

Policy implementation within the six case studies: coherence of the policy mixes

The case studies show Member States have used different instrument types directed at different target groups to improve energy efficiency. The EU outcome on used instrument types, based on the EEA PaM database or MURE database, typically also holds for the case studies: a dominance of regulation and financial instrument types. There are also some differences between the cases: taxes and fiscal instruments are not used in all case studies, namely Cyprus, Czech Republic (although this could also be a result of incomplete reporting), albeit it only constitutes one or two PaMs in the cases where it is reported. Also the importance of information and education measures is different, and it is particularly important in Cyprus and France.

In almost all cases owners/tenants are the most targeted group by individual PaMs. This is expected because of their diversity and of their direct impact on the energy efficiency of buildings due to the construction of more efficient new buildings or to retrofitting.

In all selected Member States, the policy mix tends to increase in complexity with time as more and more PaMs are implemented. Only the data from the Netherlands show more dynamism with a significant number of PaMs expired and replaced by other policies. To analyse the internal coherence, a cross table was made for all case studies of the target audience and the instrument types, see Table 2. This helps identify what kind of instrument types are combined. As indicated in the literature study, combinations of policy instruments are now believed to be more effective than single instruments. Nevertheless, not all instruments are complementary. Theory can thus be used to see whether interactions between instrument types are likely to have a complementary, neutral or overlapping effect.

Table 2. Cross tables of target audience and instrument types of PaMs in buildings (Odyssee-MURE, 2017 & 4th NEEAP submissions in April 2017): Number of PaMs, expressed in relative terms to the country total.

		Financial	Legislative Normative	Legislative Informative	Fiscal / Tariffs	Information / Education	Voluntary agreement	Cooperative measures	TOTAL # PaMs
Bulgaria	Financial Institutions	2%	1%	1%	1%	1%	0%	0%	
	Energy suppliers	2%	0%	2%	0%	1%	0%	0%	
	Authorities	4%	5%	8%	2%	1%	0%	2%	
	Other	0%	0%	0%	0%	0%	0%	0%	
	Building professionals	13%	13%	5%	0%	4%	0%	0%	
	Owners/Tenants	10%	15%	2%	0%	2%	0%	0%	37
Cyprus	Financial Institutions	2%	0%	0%	0%	2%	0%	0%	
	Energy suppliers	6%	2%	1%	0%	5%	0%	0%	
	Authorities	3%	0%	0%	0%	1%	0%	0%	
	Other	12%	2%	0%	0%	14%	0%	0%	
	Building professionals	5%	7%	3%	0%	6%	0%	0%	
	Owners/Tenants	5%	10%	5%	0%	7%	0%	0%	18
Czech Republic	Financial Institutions	0%	0%	0%	0%	0%	0%	0%	
	Energy suppliers	0%	0%	0%	0%	0%	0%	0%	
	Authorities	13%	3%	0%	0%	3%	0%	2%	
	Other	10%	1%	0%	0%	7%	0%	0%	
	Building professionals	6%	7%	0%	0%	2%	0%	0%	
	Owners/Tenants	23%	13%	0%	0%	9%	0%	0%	44
France	Financial Institutions	1%	0%	1%	0%	0%	0%	0%	
	Energy suppliers	3%	0%	2%	0%	0%	1%	1%	
	Authorities	3%	1%	4%	0%	3%	1%	3%	
	Other	1%	1%	2%	0%	1%	1%	1%	
	Building professionals	4%	6%	3%	1%	3%	1%	1%	
	Owners/Tenants	15%	14%	6%	7%	11%	0%	0%	73
the Netherlands	Financial Institutions	0%	0%	0%	0%	0%	0%	0%	
	Energy suppliers	1%	0%	2%	0%	0%	0%	0%	
	Authorities	2%	1%	1%	0%	0%	1%	0%	
	Other	2%	1%	1%	0%	1%	0%	0%	
	Building professionals	7%	4%	0%	0%	1%	0%	0%	
	Owners/Tenants	45%	2%	0%	4%	19%	3%	0%	37
Sweden	Financial Institutions	0%	0%	1%	0%	1%	0%	0%	
	Energy suppliers	1%	1%	1%	0%	1%	0%	1%	
	Authorities	1%	0%	1%	0%	3%	0%	0%	
	Other	1%	0%	0%	0%	1%	0%	4%	
	Building professionals	7%	7%	3%	0%	10%	0%	3%	
	Owners/Tenants	10%	12%	12%	3%	6%	0%	4%	48

The strong dominance of legislation/regulation and financial instruments is reflected in these cross table, which suggests that both instruments are used for the same target groups. Some financial instruments such as loans and grants are not very complementary and therefore having many similar policy instrument types targeted at the same group is not necessarily very effective. Financial and legislation instrument types might also overlap and therefore it is possible that the outcome is lower due to negative interaction effects. This is mostly the case of the group of owners/tenants in the case studies, for example in Bulgaria, Czech Republic and France. On the other hand, owners/tenants of buildings are also often the target group of information and education instruments, which has a positive effect and reinforces the impact of financial and legislative instrument types as well as all other instrument types. Information and education appears to be used for all relevant target groups (but not often for financial institutions and energy suppliers) in all case studies. Theory suggests that taxes are also complementary with all other instrument types, but are not used explicitly in all case studies as a tool to improve energy efficiency in buildings. As Rosenow et al. (2016) pointed out, countries take very different views on taxation of energy of different types and across different sectors. Using high taxes to stimulate energy efficiency might be politically unacceptable or not in line with other policy goals.

It is also clear from the cross tables, that the number of individual PaMs does not necessarily mean that a more diverse policy mix is used for the specific target groups. France, which has the most individual PaMs of the case studies, also has a more diverse policy mix for the different target groups. However, despite the lowest number of PaMs reported, Cyprus appears to have a more complex policy mix than the Netherlands and the Czech Republic.

In their NEEAPs, the Member States report the impact of energy efficiency improvements on final and primary energy consumption. Some Member States also report the impact of individual energy efficiency PaMs. This makes it possible to look closer to realized ex post energy savings (and in some cases even avoided GHG emissions) of PaMs. However, the low availability of ex post evaluations or action plans in literature and the strong diversity of ways to calculate and express savings or efficiency improvements makes any comparison difficult. In that sense, the IDA decomposition analysis makes it possible to have a more consistent overview of ex-post reductions due to energy efficiency improvements for each of the case studies. The split between the different driving forces influencing overall energy consumption or GHG emissions makes this possible.

Greenhouse gas decomposition of residential sector in the six cases

Table 3 and Figure 1 show the main results of the chained multiplicative IDA for CO_2 emission in the residential sector between 2005 and 2015. The numbers shown correspond to the ratio of CO_2 emissions per factor in 2015 and 2005 for each country and for the European Union, e.g., for a ratio of 1.2, for instance, CO_2 emissions in 2015 were 20% higher than the CO_2 emissions in 2005.

Table 3. Results of multiplicative IDA for the residential sector in six countries and EU28, 2005-2015.

Country	Activity	Intensity	Fuel	Coefficient	Weather	Total
Bulgaria	1,1312	0,9589	1,0182	0,9762	0,9386	1,0120
Cyprus	1,0178	0,9959	0,8764	0,9968	0,9867	0,8738
Czech Republic	1,1028	0,9748	0,9644	0,9997	0,9332	0,9672
France	1,0433	0,9445	0,8856	0,9956	0,9496	0,8251
Netherlands	1,0516	0,9016	0,9717	0,9992	0,9948	0,9157
Sweden	1,0819	0,9360	0,6549	1,0528	0,9812	0,6850
EU-28	1,0494	0,9426	0,9316	1,0001	0,9538	0,8790

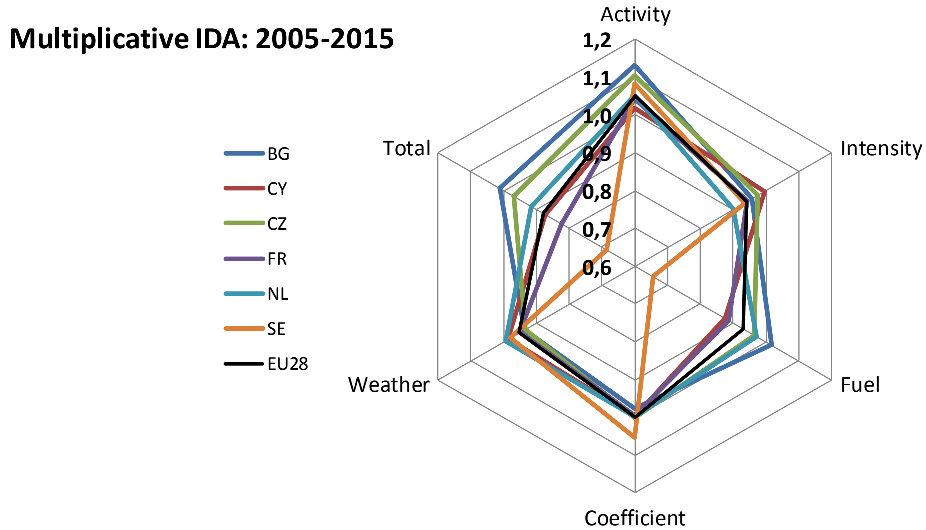

Figure 1. Results of multiplicative IDA for the residential sector in the 6 countries and EU28, 2005-2015.

Overall, the results show that Bulgaria is the only country with an increase of total CO_2 emissions (1.2% higher than unit,) between the considered time horizon (with a total effect on the aggregate higher than 1[2]). All other five countries, have reduced their CO_2 emissions in the residential sector between 2005 and 2015 due to improvements in energy efficiency (reduced energy intensity), to higher use of zero or low carbon fuels (fuel mix) and due to weather variations leading to lower energy demand for heating and cooling.

Sweden is the country who has performed best over the period, as CO_2 emissions (factor 'Total') were reduced to over 30%, which is explained by the significant negative effect of the fuel mix. Moreover, from the six countries analysed, half of them performed better than the EU28 (calculated based on the input data for the EU28 as in Eurostat): Cyprus, France and Sweden. Besides Bulgaria, Czech Republic and Netherlands performed worse compared to EU28.

The intensity factor contributed negatively, i.e. implying a reduction, to the overall variation of CO_2 emissions in all six countries and EU28 as all of them resulted in an intensity factor lower than unit. This indicates that energy efficiency policies contributing to the energy intensity have been somewhat effective, contributing to CO_2 mitigation in contrast to the positive effect caused by the economic activity. The country with best performance on energy intensity was the Netherlands, as it has achieved a CO_2 mitigation due to energy intensity reduction of almost 10% between 2005 and 2015, which is also higher than the EU28 improvement, which was below 6%. Sweden has also performed better than the EU28 on improving energy efficiency, as it reached a 6.4% CO_2 abatement due to energy intensity reduction. The intensity effect shows that Cyprus and Czech Republic performed worse on reducing energy intensity, but this was somewhat offset by the increased use of fuels with lower carbon content.

Because it splits the CO_2 emissions variation between 2005 and 2015 into different effects, the CO_2 emissions decomposition results provides a more accurate assessment of the impact of energy intensity variations on the level of mitigated emissions for the six countries considered in this study. In that context, the next section will bring together the quantitative assessment of the IDA with the qualitative policy assessment of energy efficiency policies related to residential buildings in order to evaluate the effectiveness of policy mixes in the six countries considered.

[2] Which corresponds to a relative value of 1.012, where the numerator is the CO_2 emissions level in 2015 and the denominator is the CO_2 emissions level in 2005, as explained in Equation 1.

Effectiveness of Policy Mixes: linking the IDA results to policy mixes implemented in the six cases

Bulgaria:

Both the energy IDA performed by the European Commission (EC, 2017) as the CO_2 emissions IDA conducted in this study show that although some positive impact on energy efficiency was observed between 2005 and 2015, higher activity and the use of more carbon intensive fuels contributed to higher energy consumption (by 3.7%) and CO_2 emissions (by 1.2%) in 2015 relative to 2005.

Table 2 shows that the financial, legislative and information measures are targeted to a rather broad audience, although the latter type of PaMs is less frequently implemented. Given the high number of legislative/normative measures on the one hand and financial measures on the other hand, there is on average a strong overlap between the implemented PaMs that relates to a somewhat modest performance on energy consumption and CO_2 emissions reduction due to energy savings.

Cyprus:

In Cyprus, the dominant fuel consumed in households has changed over the last 25 years. In 1990 petroleum products were most commonly used (64 %), but since then the share of electricity and renewables have increased to 41 % and 21 % respectively in 2015 (Eurostat, 2017). In 2015, renewable energies contributed 16 % of final energy consumption from buildings (households and services) in Cyprus (Eurostat, 2017). This is confirmed by the IDA results as impacts on CO_2 emissions are attributed to the use of cleaner fuels as the fuel mix effect contributes to a 12% reduction of emissions. It contrasts with the energy intensity effect, which reduction impacted the total variation in less than 1%.

Regarding policies, there is a strong dominance of legislative, financial and information instrument types, but distributed among different audiences. As Cyprus scores the worst on CO_2 emissions due to energy savings, the IDA analysis indicates that 1) country's strategy for CO_2 mitigation has fuel substitution as the key driver and 2) the overlapping effect of specific instruments focusing on different audiences might have generated counterbalancing effects compromising energy savings, which should be subject of further investigation.

Czech Republic

Despite the positive economic growth (driving up the activity effect), the country was able to reduce its CO_2 emissions between 2005 and 2015 by 3%. Although the IDA indicates that weather variations have contributed to lower energy consumption, the CO_2 emissions reductions due to energy efficiency accounts for a limited reduction of 2.5% of the total. The decomposition analysis of the Czech Republic by Odyssee-MURE (2017) suggests that energy savings (from energy efficiency improvements) have increased from 2000 to 2010.

There is a strong dominance of financial, legislative and information measures. Given the high number of financial measures, there is on average an overlap between some of the implemented PaMs. Concerning the target audience, owners/tenants, building professionals, and authorities are mainly addressed, but overall different target audiences are covered over the whole time period. In the group of owners/tenants relatively more financial instruments are provided, while for building professionals more legislative PaMs have been implemented.

France

EC (2017) shows that energy intensity contributed significantly (by 25%) to the reduction of final energy consumption, although offset by increased activity. Regarding CO_2 emissions, the IDA decomposition shows that, between 2005 and 2015, energy efficiency contributed to more than 5% of CO_2 emissions reductions in the country. However, the most important effect contributing to CO_2 mitigation was the fuel mix, impacting on CO_2 abatement by 11% and leading France to score as second best on the total IDA result (behind Sweden) The decomposition analysis of Odyssee-MURE quantifying the impact of energy savings on total energy consumption shows that there has been continuing progress in energy efficiency in residential buildings, larger than decreases in absolute energy consumption (Odyssee-MURE, 2017).

France has a long history of policies dealing with energy efficiency in buildings, as well as a big diversity of types of measures implemented with different target audiences but, still, most of them focusing on owners/tenants. Hence, there is a general tendency of overlap in the implemented PaMs. This implies that the expected savings of the individual PaMs each are likely to decrease. Nevertheless, France has been implementing a variety of measures targeting a variety of audience to improve the energy efficiency of buildings. The roll-out of long-term programs and plans, like the Law on the energy transition for green growth LTECV and the Housing energy renovation plan PREH, can guide the policy-making and improves the holistic approach or coherence of the implemented policy package.

Netherlands

The Netherlands' recent experience in energy efficiency is often cited as a prototype of best practices able to establish an innovative, market-leading approach in the household and building sectors (EPRS, 2016).

The energy consumption for heating in residential buildings shows a clear and consistent downward trend in the period 2000-2015 (Eurostat, 2017). The Odysee-MURE decomposition analysis quantifying the impact of energy savings on total energy consumption shows that there has been continuing progress in energy efficiency in residential buildings, larger than decreases in absolute energy consumption (Odyssee-MURE, 2017). The IDA decomposition shows that the country with best performance on energy intensity was the Netherlands, as it has achieved a CO_2 mitigation due to energy intensity of almost 10% between 2005 and 2015, which is also higher than the EU28 improvement, which was below 6%.

Looking closer to the implemented measures in the Netherlands, over the whole time period a strong dominance of only three types of measures are identified, namely financial, legislative/normative and information/education. In fact, financial instruments targeting owners/tenants correspond to 45% of the number of existing PaMs. BPIE (2014) points that the success of the Dutch case can be attributed to the robust transparency and accountability systems (monitoring) translated into public communication campaigns and annual progress reports on top of the policy package adopted. Moreover, the Dutch policy aims for cooperation between individuals and businesses to address barriers to implement energy efficiency measures in buildings. This might justify the concentration of policies on financial instruments for owners/tenants, although an assessment of the profile of these policies is beyond the scope of this paper.

Sweden

The energy decomposition conducted by the European Commission (EC, 2017) shows a significant amount of energy savings between 2005 and 2015, resulting in a 18% reduction of energy consumption in the residential sector. The impact of measures related to heating only amount to a 10 % share of total final energy consumption. Regarding CO_2 emissions, energy efficiency also contributed well (above 6%) to the CO_2 mitigation, but the most remarkable impact comes from the fuel mix effect, which contributes to more than 30% of the mitigated CO_2 in the period 2005-2015. This is principally a result of a large uptake of renewable energy in the district heating sector (EC, 2016). Today, Sweden has one of the highest uses of district heating in the EU. In total, the sector heats more than 50 % of all buildings, compared to 6 % in the rest of the EU (SEI, 2017). District heating has played a key role in the Swedish policies related to heating of buildings since the middle of the 20th century. However, the growth of the district heating sector is particularly notable due to the absence of any specific 'district heating policy' guiding the growth of the sector. Instead, district heating schemes have been the direct result of overarching energy and climate policies, and in particular national energy and carbon dioxide taxes are the principal policy instruments applied to improve energy efficiency and reduce greenhouse gas emissions (Swedish Energy Agency, 2015).

Overall comparison

Table 4 below provides a joint summary of the ex post qualitative assessment of PAMs and the results of the CO_2 IDA (energy intensity factor, and total CO_2 variation between 2005 and 2015) for the six countries:

Table 4. Summary of results for the six case studies, time periods between 2005-2015.

Country	Main Instrument(s)	Target Audience	Overlapping Characteristics	CO_2 reduction due to Energy Intensity	Total CO_2 Variation
Bulgaria	Financial and Legislative	Distributed	High - Target Audiences	-4,1%	1,2%
Cyprus	Financial, Legislative, Information	Distributed	High - Target Audiences	-0,4%	-12,6%
Czech Republic	Financial, Legislative, Information	Distributed	High - Target Audiences	-2,5%	-3,3%
France	Distributed	Focus on Owners/Tenants	High - Instrument Type	-5,6%	-17,5%
Netherlands	Financial	Focus on Owners/Tenants	Low	-9,8%	-8,4%
Sweden	Distributed	Focus on Owners/Tenants	High - Instrument Type	-6,4%	-31,5%

Energy efficiency improvements in the building sector are hindered by various barriers, each of which needs to be addressed by different types of measures. The development of a balanced policy mix which includes several types of measures is required for effective energy efficiency policies. The assessment of energy efficiency policy mixes based on CO_2 decomposition analysis for the six countries provides some specific insights on effectiveness of policy implementation for energy efficiency.

In the case studies, a strong dominance of regulation and financial instrument types is detected and the audience of owners/tenants is mainly addressed. However how these policies are distributed among audiences varies between countries. It might explain why the energy intensity factor contributed negatively, i.e. implying a reduction, to the overall variation of CO_2 emissions for the six countries. In fact, results show that the three countries scoring best on the energy intensity factor in the IDA analysis have a focus on financial and legislative instruments, although other instruments are also considered.

In that context, as literature indicates that financial measures have the highest impact on energy efficiency, the analysis show that countries with the best IDA results related to energy intensity (namely Netherlands, Sweden and France) not only adopted financial instruments, but set focus on owners/tenants as their main target audiences. Bulgaria and Cyprus, however, who scored lower on the energy intensity effect, distributed their financial instruments among different audiences. This indicates that distributing these type of policies among different actors might compromise effectiveness of the policy mix, which would be related to overlapping, coherence matters, etc. Further investigation is recommended on this subject in order to better understand this correlation.

Literature also indicates that information measures, which contain labelling, surprisingly lead to lower energy efficiency levels. In this assessment, Cyprus has 35% of its policies based on information measures and it had the worst result of energy intensity in the CO_2 emissions IDA. The quantitative assessment of the study identified only one labelling measure within information policies in Cyprus, indicating that this effect should be analyzed with more detail.

As theory suggests that taxes are complementary to all other instrument types, the IDA decomposition indicated the lowest impact of the intensity factor on the CO_2 emissions in Cyprus and the Czech Republic. These two countries have no fiscal/tariffs instruments reported in the building policy mixes. As Rosenow et al. (2016) pointed out, countries take very different views on taxation of energy of different types and across different sectors. Using high taxes to stimulate energy efficiency might be politically unacceptable or not in line with other policy goals.

The strong dominance of legislation/regulation and financial instruments focused on one target group, mainly owner/tenants, can also imply an overlap between measures, like some financial instruments such as loans and grants which are not very complementary[3]. Therefore having many similar policy instrument types targeted at the same group is not necessarily very effective, as indicated by the case studies France, Bulgaria and Czech Republic, which are performing less than the EU28 average concerning the intensity factor. However, the case of the Netherlands shows that concentrating policies might be effective, if implementation is coherent, transparent and efficiently monitored.

The number of individual PaMs not necessarily means that a more diverse policy mix is used for specific target groups and that it improves effectiveness. For instance, France, which has the highest number of individual PaMs of the case studies, also has a more diverse policy mix in the different target groups, but scores worse than Sweden, which also present a good level of policy mix, but with a reduced number of individual PaMs and less distributed among audiences.

Three out of the six countries, namely Sweden, France and Cyprus, have their CO_2 emissions reduction significantly driven by the fuel mix factor (from 11% to 35% of CO_2 emission reduction between 2005 and 2015). Moreover, apart from the Netherlands and Sweden, the energy intensity effect resulted in less than 5% of CO_2 mitigation between 2005 and 2015. This indicates that the main driver of CO_2 abatement between 2005 and 2015 is fuel substitution, and not energy efficiency in most of case studies, although the result for EU28 shows a balance between energy intensity and fuel mix effect, both responsible for 6% to 7% of CO_2 mitigation. In the light of the winter package and the need to put 'energy efficiency first', Member States should explore their energy savings potentials to tackle their CO_2 emission targets and the approach adopted in this study provides evidence on which extend this has been the case for member states and EU.

Conclusions

This paper conducted an ex post evaluation of national energy efficiency policy mixes in the residential sector. The incorporation of a CO_2 emissions IDA to the policy mix assessment allowed further insights on effectiveness by identifying relationships between the energy intensity factor of and the mix of instruments and targeted audiences in each country. However, issues regarding data availability limit the scope the assessment. Hence, this study provided a basic assessment of instruments in different countries, their impacts on CO_2 mitigation and indicated other drivers underlying emission reductions. This ex post assessment could be replicated to other MS, providing further insights on successful cases and how to move forward with energy efficiency policies in the light of the 'winter package'. Moreover, improvements regarding the considered indicators in both PaM evaluation (such as end-use targeted by PaMs besides audiences) and the CO_2 IDA (such as considering household's floor area for heating consumption as activity indicator) are also propositions of further work to enhance the assessment.

Main findings show that a strong dominance of financial and legislative instruments focusing on owners/tenants lead to the highest levels of CO_2 mitigation through energy savings, as shows the case of Netherlands, Sweden and France. Moreover, as information instruments may not lead to effective results (as the case of Cyprus), the absence of fiscal instruments may also hinder energy efficiency policies (such as in Cyprus and Czech Republic). Furthermore, results show that effectiveness is not related to the number of PaMs directed to energy efficiency, but rather to how they are distributed among instruments and target groups. Cooperation between agents and transparency in the monitoring process seem to count as well (as the case of the Netherlands). Last, the results of the IDA show that for the half of the MS considered, fuel substitution seems to be the main driver of CO_2 mitigation and that MS seem to still lack an integration of energy and climate policies to tackle CO_2 emissions in the residential sector.

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[3] Subject to the profile of the building stock in each country.

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Annex A

The multiplicative LDMI I CO_2 emissions decomposition was conducted based on the following equations:

CO_2 emissions ratio between two periods as of Equation 1:

$$R = \frac{C_{t_2}}{C_{t_1}} = R_{act} . R_{int} . R_{fuel} . R_{EF} . R_{Wth}$$

Where:

$$R_{act} = \frac{C_{act,t_2}}{C_{act,t_1}} = exp^{\left\{W'_{ij,\Delta t} \cdot \ln\left(\frac{Q_{t_2}}{Q_{t_1}}\right)\right\}} \quad - \quad \text{(Equation 1)}$$

Intensity Effect R_{int}:

$$R_{int} = \frac{C_{int,t_2}}{C_{int,t_1}} = exp^{\left\{W'_{ij,\Delta t} \cdot \ln\left(\frac{I_{t_2}}{I_{t_1}}\right)\right\}} \quad - \quad \text{(Equation 2)}$$

Fuel Mix Effect R_{fuel}:

$$R_{fuel} = \frac{C_{fuel,t_2}}{C_{fuel,t_1}} = exp^{\left\{W'_{ij,\Delta t} \cdot \ln\left(\frac{F_{ij,t_2}/F_{i,t_2}}{F_{ij,t_1}/F_{i,t_1}}\right)\right\}} \quad - \quad \text{(Equation 3)}$$

Emission Coefficient Effect R_{EC}:

$$R_{EC} = \frac{C_{EC,t_2}}{C_{EC,t_1}} = exp^{\left\{W'_{ij,\Delta t} \cdot \ln\left(\frac{EC_{ij,t_2}}{EC_{ij,t_1}}\right)\right\}} \quad - \quad \text{(Equation 4)}$$

Weather Effect R_{Wth}:

$$R_{W} = \frac{C_{Wth,t_2}}{C_{Wth,t_1}} = exp^{\left\{W'_{ij,\Delta t} \cdot \ln\left(\frac{Wth_{t_2}}{Wth_{t_1}}\right)\right\}} \quad - \quad \text{(Equation 5)}$$

Weight factor $W'_{ij,\Box T}$ for the multiplicative LDMI I:

$$W'_{ij,\Delta t} = \sum_{i}^{sec} \sum_{j}^{fuel} \frac{(C_{ij,t_2} - C_{ij,t_1}) / (\ln C_{ij,t_2} - \ln C_{ij,t_1})}{(C_{t_2} - C_{t_1}) / (\ln C_{t_2} - \ln C_{t_1})} \quad - \quad \text{(Equation 6)}$$

Where factors correspond to:
R: CO_2 emissions aggregate relative to the multiplicative index decomposition analisys;
C_{t1}: CO_2 emissions in period t_1 in the considered country/region;
C_{t2}: CO_2 emissions in period t_2 in the considered country/region;
R_{act}: Relative CO_2 emissions variation between t_1 and t_2 due to the activity effect in the considered country/region;
$C_{act,t}$: CO_2 emissions in the considered country/region in period/year t due to activity;
Q_t: activity indicator in period t.
R_{int}: Relative CO_2 emissions variation between t_1 and t_2 due to the intensity effect in the considered country/region;
$C_{int,t}$: CO_2 emissions in the considered country/region in period/year t due to intensity;
I_t: intensity indicator in period t.
R_{fuel}: Relative CO_2 emissions variation between t_1 and t_2 due to the fuel mix effect in the considered country/region;
$C_{fuel,t}$: CO_2 emissions in the considered country/region in period/year t due to the fuel mix;
$F_{ij,t}/F_{i,j}$: fuel mix indicator in period t.
R_{EC}: Relative CO_2 emissions variation between t_1 and t_2 due to the emission coefficient effect in the considered country/region;
$C_{EC,t}$: CO_2 emissions in the considered country/region in period/year t due to emission coefficients (fuel's carbon content);
$EC_{ij,t}$: emission coefficient indicator in sector 'i' for fuel 'j' in period t.
R_{Wth}: Relative CO_2 emissions variation between t_1 and t_2 due to the weather effect in the considered country/region;
$C_{wth,t}$: CO_2 emissions in the considered country/region in period/year t due to weather;
Wth_t: weather indicator in period t;
Cij,t: CO_2 emissions (CO_2, CH_4, N_2O, etc) in period/year 't', in sector 'i', due to fuel 'j' consumption, in the considered country/region.