Papeles de Energía

Instrumentos para la eficiencia energética

Nº27
Abril 2025

funcas

Papeles de Energía

Edita: **Funcas**
Caballero de Gracia, 28. 28013 Madrid

Diseño y maquetación: **Funcas**

Impresión: **Cecabank**

ISSN impreso: 2530-0148
ISSN digital: 2445-2726

Depósito Legal: M-7537-2016

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INTRODUCCIÓN

Instrumentos para la eficiencia energética

En general, todos los planes de descarbonización de nuestras economías incluyen el ahorro y la eficiencia energética como uno de los vectores principales para lograr la reducción de emisiones a la vez que se mantiene el nivel de satisfacción de servicios energéticos demandados por los consumidores.

Así, por ejemplo, la Agencia Internacional de la Energía, en su *World Energy Outlook*, considera que, para cumplir con los objetivos de cambio climático, la demanda de energía global debe reducirse un 20 % frente al nivel actual, o un 26 % frente al nivel esperado sin cambios en las políticas. Lo mismo sucede a nivel europeo o español. Por ejemplo, el Plan Nacional Integrado de Energía y Clima, en su última actualización, plantea mejorar la eficiencia energética primaria en un 43 %, o, en otros términos, una mejora anual de la intensidad energética final del 3,1 % anual hasta 2030.

Sin embargo, y más allá de las reducciones de consumo energético asociadas a la destrucción de la demanda industrial (como la asociada a la reciente crisis de 2022), lo cierto es que la eficiencia energética no avanza tan rápido como debería. Por ejemplo, frente a las reducciones anuales de la intensidad energética del 4 %, que serían las estimadas por la Agencia Internacional de la Energía para cumplir con los objetivos de descarbonización, los últimos años solamente muestran reducciones de 1-2 %.

Quizá una de las razones para este progreso menor de lo esperado es que, a pesar de las evidentes ventajas para economías y consumidores, tanto en término de coste como de reducción de emisiones, es complejo encontrar un modelo de negocio viable para la eficiencia energética, en el que los agentes que deban movilizarla puedan rentabilizar sus esfuerzos. Existen distintas razones para ello: dificultad para acceder a la financiación, percepción de riesgo por los consumidores, información asimétrica o directamente falta de información, falta de atención…

Las políticas que pretenden promover la eficiencia energética deben pues diseñar instrumentos capaces de solventar estos problemas. En este número revisamos algunos de los instrumentos más habituales, desde distintas perspectivas.

Un primer instrumento es el que ayuda a financiar la inversión de los agentes mediante subsidios, que pueden ser proporcionados directamente, o bien canalizados a través de los llamados certificados blancos (o, en España, Certificados de Ahorro Energético o CAEs).

Louis-Gaëtan Giraudet, investigador del Centro Internacional de Investigación sobre Medio Ambiente y Desarrollo (CIRED), nos ofrece una amplia comparativa del funcionamiento de los subsidios (incluyendo los certificados blancos) para rehabilitación residencial en Francia, un país con un catálogo muy completo de este tipo de programas.

En general, estos programas son efectivos a la hora de aumentar las inversiones en eficiencia, aunque con un gran número de participantes "inframarginales", es decir, que invertirían aun en ausencia de subsidios. Esto los hace poco eficientes en el uso de los fondos públicos. Sin embargo, cuando se añaden el resto de beneficios de estos programas (mejoras de salud, acceso a la financiación, etc.) entonces sí pueden ser atractivos.

Sin embargo, el autor recuerda que la clave reside en el diseño: así, los subsidios "por unidad" y no "por gasto" generan menos distorsiones; su focalización en los hogares vulnerables los hace más eficientes (aparte de más equitativos); y los programas gestionados a nivel local muestran propiedades más favorables. Los programas gestionados directamente por las compañías energéticas no presentan atributos más positivos que los públicos, lo que puede recomendar fusionarlos.

Como decíamos, uno de los programas analizados por Giraudet es el de certificados blancos, establecidos en Francia en 2006. Este sistema consiste en fijar una cuota de ahorro energético para agentes como los comercializadores de energía, y permitirles cumplirla mediante la presentación de certificados de ahorro. Estos certificados, a su vez, se emiten contra la instalación de equipos que ahorren energía (por ejemplo, una caldera más eficiente, o un equipo de recuperación de calor). Quizá su atributo más interesante es que pueden ser comprados y vendidos en un mercado, que, por tanto, pone precio a dichas actuaciones, y que a través de esa señal permite que sean los agentes más eficientes los que las realicen, y también que se identifiquen las actuaciones más económicas.

En España han sido recientemente implantados, y **Jon Macías**, Chief Commercial Officer de EDISON NEXT, y presidente de la Junta de la Asociación Nacional de Empresas de Eficiencia Energética (ANESE), nos muestra el presente de los CAEs en España, y sus perspectivas de futuro.

Los CAEs se implantaron en España en 2023 para que las empresas pudieran sustituir las aportaciones económicas que hasta ese momento hacían al Fondo Nacional de Eficiencia Energética (FNEE) por ahorros de energía certificados mediante los citados CAEs. Las actuaciones que permiten generar CAEs están recogidas en un catálogo con 114 fichas, y además se permiten acciones singulares. Entre estas actuaciones están los sistemas de monitorización energética, el reemplazo de calderas, o el cambio de sistemas de iluminación.

En España los sujetos obligados a ahorrar energía son las comercializadoras de gas y electricidad, y los operadores al por mayor de productos petróliferos y GLP, que son por ello los interesados en adquirir estos CAEs para evitar la contribución económica al FNEE.

El balance de implementación de los CAEs hasta ahora es positivo: en 2024 se realizaron más de 1.200 actuaciones, con un ahorro de 2 TWh de energía final, que equivale al 1 % de las emisiones anuales de CO_2 de la industria. Los ingresos estimados por los CAEs son de 230 millones de euros. Ahora bien, la mayoría de los CAEs vienen de 78 actuaciones singulares en el sector industrial.

El autor considera que el futuro del sistema es prometedor, pero requiere que tanto el sector público como el privado sigan apostando por su desarrollo. En este sentido, las obligaciones de ahorro (y, por tanto, la necesidad de CAEs) son crecientes en los próximos años, por lo que se espera que este mercado crezca hasta unos 1.700 millones de euros.

Otro instrumento que trata de incentivar la eficiencia energética son las etiquetas energéticas, promovidas por la Unión Europea e implantadas en los Estados miembros. Las etiquetas tratan de solucionar los problemas de falta de información por parte de los consumidores, proporcionando datos sobre los consumos esperados, y en ocasiones, sobre los gastos previstos.

Ivan Petrov y **Eleanor Denny**, de Trinity College Dublin, nos ofrecen una visión amplia de la evidencia empírica reciente acerca del uso de las etiquetas energéticas en dos de las mayores compras que hacen los hogares: viviendas y vehículos. Tras introducir la problemática general de la eficiencia energética de una forma clara y accesible, los autores pasan a discutir el papel que la información vía etiquetas juega en la compra de viviendas y vehículos. Básicamente, las etiquetas tratan de resolver el fallo de información, que a su vez, supone una barrera para la inversión en eficiencia.

En su revisión de la literatura, los autores encuentran que las viviendas más eficientes se venden a precios mayores, y que, por tanto, el etiquetado mejora el bienestar en el mercado inmobiliario, en particular en el mercado del alquiler, en el que la información sobre la eficiencia energética tiene aún mayor valor. En cuanto a los vehículos, las etiquetas no se han demostrado tan efectivas, quizá porque hay otros atributos mucho más importantes para el comprador, o porque el consumidor no termina de "fiarse" de la información de las etiquetas, a la vista de algunas divergencias observadas entre consumos reales y teóricos.

En cualquier caso, los autores advierten que para que las etiquetas funcionen bien es necesario que trasladen la información de forma entendible y realista. Y también que no son capaces de solucionar todas las barreras para la eficiencia energética.

Otro ámbito en el que las etiquetas energéticas han demostrado su capacidad de incentivar la compra de equipos más eficientes es en los electrodomésticos. **Elena López-Bernabé**, de la Universidad de Castilla-La Mancha, y **Amaia de Ayala** e **Ibon Galarraga**, de la Universidad del País Vasco y BC3, resumen sus investigaciones sobre el caso de las lavadoras en España.

En este caso, los investigadores encuentran que el consumidor está dispuesto a pagar una prima del 11 % sobre el precio final para las lavadoras con mayor nivel de eficiencia. Esta prima además ha aumentado desde las primeras estimaciones hace más de 10 años. La prima es inferior a la que se encuentra para frigoríficos (que se utilizan más) o superior a la de otros electrodomésticos de menor uso, reflejando, pues, que el consumidor se comporta de forma racional. Además, también se observan diferencias en las primas en función de criterios culturales o medioambientales.

Los autores subrayan el papel que puede jugar el conocimiento de esta prima, por ejemplo, a la hora de diseñar políticas de subsidios que eviten el comportamiento inframarginal citado anteriormente. Y también recuerdan la importancia de las políticas de promoción e información para que los consumidores respondan a estas etiquetas.

En todo caso, y como siempre, les recomiendo leer los artículos al completo, ya que encontrarán múltiples resultados y reflexiones de interés acerca de la mejor forma de promover la eficiencia energética, clave para la transición.

How to best design subsidies for home energy retrofits? A literature review*

*Louis-Gaëtan Giraudet***

Abstract

This paper reviews the evidence on the effectiveness of subsidy programs for home energy retrofits, looking in particular at which design features yield the greatest benefits. It draws heavily on the French subsidy portfolio, which is of unparalleled size and diversity, thus perfectly lending itself to comparative analysis. Subsidy programs are found to be effective at increasing household investment, saving them energy, and creating jobs in the renovation industry, but not as much as predicted, partly due to inframarginal participation. Effectiveness tends to be higher with per-unit subsidies, as opposed to *ad valorem* ones; when lower-income households are entitled greater benefits; when subsidies are publicly-funded, as opposed to utility-funded; and when they are deployed at the local, as opposed to national, level.

Keywords: Energy efficiency, subsidies, home retrofit.

1. INTRODUCTION

Subsidy programs for home energy retrofits are a widespread policy tool in rich economies (Kerr and Winskel, 2020). As of 2025, the International Energy Agency (IEA) has recorded 143 national government spending programs on energy-efficient building[1]. On allocative grounds, such programs are considered an adequate tool to address at once several market and behavioral frictions hindering energy efficiency investment. While reducing CO_2 emissions is usually their primary motivation, they are increasingly recognized to generate a number of co-benefits – health improvements through reduced exposure to cold-related illness, mostly prevalent among low-income households (Dervaux and Rochaix, 2022; Roberdel *et al.,* 2025); easier access to credit, which is essential to cover upfront costs in the thousands or even tens of thousands of euros; or increased attention to the long-term benefits of retrofit investments (Allcott and Greenstone, 2024). In addition, from a political economy perspective, subsidies tend to receive stronger support from both consumers and the renovation industry than

* I thank Pedro Linares for inviting me to produce this note, which gave me the opportunity to revisit a great deal of my own research. On this occasion, I felt gratitude for the co-authors with whom I contributed to this literature, and I want to thank them here – Pille-Riin Aja, Ilya Eryzhenskiy, Matthieu Glachant, Sébastien Houde, Joe Maher, Marie-Laure Nauleau, Jean-Philippe Nicolaï, Philippe Quirion, Mariona Segú and Lucas Vivier.

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1 Source : IEA's Policies Database (https://www.iea.org/policies), as of February 6, 2025.

does pricing CO_2, the textbook remedy to the climate change externality (Douenne and Fabre, 2020; van der Ploeg, 2025).

Existing subsidy programs exhibit widely differing designs. First, they can be *ad valorem*, when subsidy rates are proportional to the investment cost, and per unit when amounts are proportional to the energy savings generated. Second, they can more or less finely target different household groups, based on income level or other relevant characteristics (*e.g.,* urban versus rural). Third, while most programs are funded by public bodies, some are funded by private bodies. The IEA (2020) has recorded 49 utility-funded energy efficiency programs in 24 countries, usually implemented to comply with a government-imposed energy efficiency obligation. Fourth, public programs can be funded by the national government or more local jurisdictions.

Empirical evaluations of subsidy programs have focused on assessing their impact along several dimensions – take-up, looking at both the extensive and intensive margins of investment; induced energy savings and how well they match engineering predictions; and, since more recently, job creation in the retrofit industry. This literature is by now rich enough so general conclusions can be drawn about subsidy effectiveness. Moreover, while existing evaluations have focused on individual programs and therefore are limited in assessing how design affects performance, this gap can now be filled by comparing evaluations of different programs. In this paper, I seize this opportunity to review the literature and examine which subsidy design features yield the greatest benefits. In doing so, I bridge the – mostly empirical – literature on impact evaluation with the – largely theoretical – one on policy design. I draw heavily on the French subsidy portfolio, which is of unparalleled size and diversity, thus perfectly lending itself to comparative analysis within a given institutional context. This portfolio includes four flagship national programs with various designs – a uniform reduction of value-added tax, a public per-unit subsidy program differentiated by income level, a similar program funded by energy utilities, and a zero-interest loan program – alongside 560 sub-national programs. In 2023, the national programs alone involved €6 billion, half of which was provided by utilities (Hainaut *et al.,* 2023; PLF, 2024). This is the most generous and comprehensive portfolio of subsidy programs for home energy retrofits I am aware of.

The rest of the paper is organized as follows. Section 2 describes the French subsidy portfolio. Section 3 reviews the literature on the effectiveness of subsidy programs along several margins. Section 4 reviews which design components are most effective. Section 5 concludes.

2. THE FRENCH POLICY PORTFOLIO

In this section, I provide some background on the subsidy programs implemented in France, with a strong emphasis on national programs. I introduce them in chronological order and highlight the design features that have been most extensively studied. Further details can be found in Giraudet *et al.* (2021) and Chlond *et al.* (2023). These programs largely overlap, and they can all be claimed to cover the same investment.

2.1. VAT reduction

Since 1999, a reduced value-added tax (VAT) rate applies to home energy retrofit works, down to 5.5% from 20%. This VAT reduction at first applied to all types of retrofit works – energy-related or not. It was de facto restricted to energy-related works in 2014 when the rate was raised to 10% for non-energy-related works. This benefit is available to all households without income restriction. Assessed against the 20% default rate, as the government typically does, the implied public cost was about €1-1.5 billion per year over the 2015-2017 period (IGF, 2020). When assessed against the 10% rate applying to the closest type of investment, which arguably provides a more relevant benchmark, it is only one third of that. Overall, the VAT reduction can be considered a uniform ad valorem subsidy with a 14.5% rate when assessed against the regular 20% VAT rate or 4.5% when assessed against the 10% VAT rate.

2.2. White certificates (CEE)

In 2006, the government imposed an energy efficiency obligation on energy suppliers. Known as *Certificats d'économies d'énergie* (CEE), the program applies to suppliers of all types of fuels electricity, natural gas, fuel oil and, since 2010, gasoline – in proportion to their retail sales. Energy savings can in turn be achieved in all sectors –- residential buildings, commercial buildings, agriculture, industry, and transport. To meet their obligation, energy suppliers must actively promote investment in energy saving equipment, typically by granting subsidies. I prefer to keep as it was in the original draft: They are entitled energy savings certificates in return to each action, based on ex-ante engineering calculations expressed in lifetime-discounted kilowatthour savings (hereafter kWh_{LD}). The so-called "white certificates" are tradable, allowing a party short of their target to purchase savings from one with excess supply.

The overall obligation has been tightened every three or four years, from 54 TWh_{LD} in the first phase (2006-2009) to 850 TWh_{LD} in the third phase (2015-2018) and 3,100 TWh_{LD} in the ongoing fifth phase (2022-2025). Meanwhile, the white certificate price has varied within a narrow range of €2-4/MWh_{LD} during the first ten years of the program, before rising sharply at the outset of Phase IV in 2018 and remaining within the €6-8/MWh_{LD} range since then. Over the years, residential buildings have consistently been the main delivery sector, contributing as much as 83% savings in Phase I and as little as 50% in Phase III. These figures together imply €75 million annual spending in the residential sector in Phase I, €425 million in Phase III and a tentative €2.7 billion in Phase V.

In 2016, a sub-obligation was introduced targeting low-income households, with a separate market. Eligible households are identified as belonging to the first two quintiles of the income distribution. White certificates are doubled for households of the first quintile, with subsidies expected to be doubled as well. Three regimes therefore prevail – the top 60% of the income distribution get subsidies based on the baseline price, the 20%-40% group gets subsidies based on the low-income price and the first quintile gets twice the latter amount. Since then, however, prices in the two separate markets have not significantly differed, suggesting the sub-obligation has not yet been binding. Lastly, since 2014, the program is subject to an eco-condition – to get subsidies, households must hire contractors certified with a good-practice label called *Reconnu garant de l'environnement* (RGE).

Taking all these features together, CEE subsidies can be considered per-unit, with an amount that depends on the expected performance and that is differentiated by income level.

2.3. Zero-interest green loans (EPTZ)

In 2009, the government introduced a zero-interest loan program called *Eco-prêt à taux zéro* (EPTZ). The program allows households to borrow money for free to invest in a selection of energy-related works. Accessible without income restrictions, loans are capped at €30,000, to be repaid over a maximum period of 15 years. Banks are compensated by the government for forgone revenue on each loan. Since 2014, the EPTZ program is subject to the same eco-conditionality as CEE. After an encouraging start, the program benefited 80,000 households in 2010 before plummeting to 40,000 in 2011 and reaching a historical low of 19,000 in 2018. Accordingly, the public cost has varied widely, from €200 million in 2010 to €22 million in 2019.

By giving back interests that would otherwise be proportional to the amount borrowed, the program can be interpreted as an ad valorem subsidy, however with important qualifications. First, the implied subsidy rate varies across time – due to fluctuations of the market interest rate – and individuals – since different borrowers would typically be charged different interest rates. Second, the rate is non-linear, as several measures need to be combined for the project to be eligible.

2.4. Direct subsidies (CITE, HM, MPR)

In 2020, the government introduced its flagship program called *MaPrimeRénov'* (MPR). It was in fact the merging and rebranding of two existing programs, a tax credit program called *Crédit d'Impôt pour la Transition Energétique* (CITE) implemented in 2005, and a low-income subsidy program called *Habiter Mieux* (HM) implemented in 2010. The CITE program was available to all households without income restrictions. The tax refund was proportional to the cost of the underlying measure, making it an *ad valorem* subsidy. While the rate was initially differentiated across measures – from 10% for window replacement to 50% for heat pump installation – it became fixed at 30% for all measures in 2014. Over the 2015-2018 period, the CITE program benefited on average 1.3 million households per year, for a total public cost of €1.9 billion per year. Meanwhile, the low-income program targeted households from the bottom 30 % of the income distribution. The subsidies were primarily granted on *ad valorem* with a 50% rate, to which smaller per-unit bonuses could be added. Over the 2015-2018 period, the program benefited between 40,000 and 50,000 households per year, for an annual cost of about €240 million (Cour des Comptes, 2018).

Since the two programs were merged, the MPR subsidies have been technically quite similar to their CEE counterparts – per-unit, performance-based and income-based, however with different amounts and thresholds. Just like CEE and EPTZ, the MPR program is subject to RGE conditionality, which was already the case with CITE since 2014.

2.5. Sub-national programs

Alongside public national programs, myriad local programs exist in France. As of today, 560 local programs have been identified (Eryzhenskiy and Giraudet, 2025). 2% are implemented at the regional level – the highest tier jurisdiction – 8% are implemented at the departmental level – the second-highest tier – and 84% are implemented at the sub-departmental level, including 14% at the municipal level. Their total cost is unknown. The best documented program is operating in Essonne, a department of 1.3 million people that is part of the Ile-de-France region which also includes the city of Paris and its metropolitan area. Implemented in 2020, the *Prime Eco-logis 91* (PEL) program benefited 30,339 households between 2019 and 2022, for a total public cost of €54.3 million.

3. ARE SUBSIDY PROGRAMS EFFECTIVE?

3.1. Do subsidies foster investment?

The question of whether energy efficiency subsidies increase investment is that which has received the most attention. Specifically, researchers have been concerned with estimating the degree of inframarginal participation, that is, the number of participants that would have invested even in the absence of any incentive (Boomhower and Davis, 2014). The inability of the regulator to screen out these participants can indeed be a source of resource waste (Giraudet, 2020). That said, the deadweight loss will be limited if inframarginal participants take advantage of this opportunity to increase their spending. With varying geographical scope and methodology, existing studies point to inframarginal participants typically accounting for 50%, and not infrequently up to 90%, of total participants (Grösche and Vance, 2009; Boomhower and Davis, 2014; Alberini *et al.,* 2016; Rivers and Shiell, 2016; Houde and Aldy, 2017). This low impact on the extensive margin of investment does not seem to be compensated by a strong impact on the intensive margin, which has only been examined in a handful studies (Rivers and Shiell, 2016; Houde and Aldy, 2017).

The results are qualitatively similar in France. The policy with the longest track record, the CITE has consequently been the most studied. Using panel data on household renovation investment, Nauleau (2014) found inframarginal participation in the program to be in the 60% to 80% range between 2007 and 2010. This result was confirmed by Mauroux et al. (2014) in a difference-in-differences framework using fiscal data and by Risch (2020) in a temporal regression discontinuity framework using the same dataset as Nauleau. Risch (2020) additionally finds a significant 22% effect on the intensive margin of investment. By combining the effects on the extensive and intensive margins, the leverage effect of subsidies is typically close to 1 – one euro of public support inducing an increase in private investment of one euro, or even more (Giraudet *et al.,* 2021; Chlond *et al.,* 2023). Turning to the CEE program, using geographic cutoffs in subsidy amounts in a regression discontinuity design, Aja and Giraudet (2025) find that the program had hardly any effect on investment take-up. This lack of effect can be explained by the low white certificate price that prevailed at the time, generating subsidies that only covered 5% of the upfront cost on average. Lastly, the EPTZ program has been evaluated by Eryzhenskiy *et al.* (2023). Using panel data on household renovation investment and an eligibility restriction to newer buildings, the authors find that eligibility to the program significantly increased the number of investments by 22%, especially for low-income households, and spending by 3%. These effects however vanished after two years into the program. The pattern of effects – strong on the extensive margin, weak on the intensive one – suggests that this policy is effective at alleviating credit constraints that can be critical for low-income households. Taking these estimates together, EPTZ had a leverage effect of 1.7 in the early days of the instrument, meaning that €1 given to banks by the government for issuing loans increased household spending by €1.7.

3.2. Do subsidies deliver energy savings?

A related question is whether subsidy programs effectively save energy. From a methodological perspective, the answer to this question is conditional on the previous one – whether the subsidy triggered investment in the first place. Accordingly, the ideal evaluation setting is to proceed in two steps – first estimating the policy effect on take-up and then use it as an instrument to estimate energy savings. Unfortunately, existing datasets are rarely comprehensive enough to provide all the data and restrictions needed for causal analysis.

Notwithstanding these methodological difficulties, the induced energy savings question has been extensively studied. The results have been quite disappointing, most studies showing that effective savings significantly underperformed engineering predictions. The issue was identified in the early age of energy efficiency economics (Joskow and Marron, 1992; Hassett and Metcalf, 1995). It was revisited and confirmed recently with more modern techniques. To cite only the most frequently cited one, in a randomized control trial involving 30,000 households in Michigan, Fowlie *et al.* (2018) identify a 70% gap between predicted and realized savings. A similar order of magnitude was found in related studies (Davis *et al.,* 2014; Graff Zivin and Novan, 2016; Giraudet *et al.,* 2018).

Three main reasons have been invoked to explain the so-called performance gap. The most commented one is the rebound effect, according to which household use energy-consuming durables more intensively after having improved their energy efficiency. Impact estimates here vary from limited (Fowlie *et al.,* 2018) to strong (Davis *et al.,* 2014). Another frequently invoked reason is the pre-bound effect – the notion that engineering models overestimate energy use before investment (Sunikka-Blank and Galvin, 2012). The effect is particularly prevalent in the least-performing dwellings, which are more likely to be occupied by low-income households (Aydin *et al.,* 2019; Charlier, 2021). The third explanation, which is less studied, is quality defects, due to the information asymmetries inherent in-home energy retrofits (Giraudet *et al.,* 2018). While these problems have been studied separately, a recent study for the first time assesses their respective influence. Exploiting data from 9,800 renovations in Illinois using machine learning techniques, Christensen *et al.* (2021) identify a 51% gap between predicted and realized savings, of which they attribute 42% to quality issues, 40% to modeling errors and 6% to the rebound effect (with 14% remaining unexplained).

In France, this outcome has been studied in relation to the CEE program and the Essonnian PEL program, both using energy data made available by the energy network operator. Wald and Glachant (2024) find that the CEE program reduced energy consumption by less than 1% between 2017 and 2021. Importantly, they find that actual savings were only 49% of predicted ones, thus uncovering a performance gap in line with that of other studies. In the case of the PEL program, Eryzhenskiy and Giraudet (2025) find that eligibility to the program reduced natural gas consumption by 8% compared to neighboring municipalities from other departments.

3.3. Do subsidies create jobs?

Besides fighting climate change externalities and providing co-benefits to households, energy efficiency subsidies are also meant to provide a stimulus to the renovation industry. This goal has been little studied. Interestingly, the few studies we are aware of on the issue both focus on France. Using regulatory changes that significantly expanded the subsidy amounts awarded to households under the CEE program, Cohen *et al.* (2024) find that €1 million of spending from utilities created 1.4 jobs in the renovation industry. Using similar industry data and comparing Essonnian municipalities and non-Essonnian ones, Eryzhenskiy and Giraudet (2025) find a higher estimate of 20 jobs created per million euro spent. This could be explained by the more intense publicity made by the local program administrator – a point we will return to.

3.4. Do existing programs close the energy efficiency gap?

The impacts reviewed so far have been estimated in reduced form. While they provide useful guidance as to what outcome can be expected from subsidy programs, they are not necessarily informative about their full welfare effects, which in turn depend on the different goals assigned to them (Allcott and Greenstone, 2024). Indeed, as said earlier, energy efficiency subsidies have the ability to address at once multiple market and behavioral failures that add up to discourage investment in energy efficiency – a phenomenon known as the energy efficiency gap (Jaffe and Stavins, 1994). These market failures chiefly include the CO_2 externality, but also credit constraints, cold-related illness, present bias, the landlord-tenant dilemma and coordination problems in multi-family housing. Whenever one of these problems is corrected, it is expected that energy efficiency and economic efficiency increase hand in hand.

Hahn *et al.* (2024) have developed a Marginal Value of Public Funds (MVPF) indicator that translates the welfare effects of climate policies into a single metric, thus allowing for comparison between them. Applying it to over 90 policies implemented in the United States, they find that subsidies to home energy retrofits (also called weatherization) have MVPF values around 1 – slightly below or slightly above. While this implies that every dollar of public money induces about one dollar of welfare gains, they note that subsidies for other climate change mitigation measures – such as wind power and solar panels – entail much higher MVPFs. These works, however, focus on the climate change externality as the main market failure to address.

France provides an interesting case study to take a broader perspective, owing to the empirical estimates available there to quantify ancillary market failures. In microsimulation work incorporating the frictions listed above and factoring in the behavioral responses estimated in empirical works, Vivier and Giraudet (2024) find that existing national programs – VAT reduction, MPR, CEE and EPTZ – together help close half of the energy efficiency gap in the French residential sector. Specifically, they close about two thirds of gap along the energy efficiency dimension but only one third of it along the economic efficiency dimension. Importantly, they find that total spending (from both the government and utilities) is commensurate with that needed to fully close the gap. This implies that existing programs are not designed in the best possible way. Let us review now what design features yield the greatest benefits.

4. WHAT DESIGN FEATURES ARE MOST EFFECTIVE?

We review theoretical works and compare the results of different empirical evaluations to discuss the relative merits of four design features – *ad valorem versus* per-unit regime, targeting of certain household groups, public versus utility funding and national versus local administration.

4.1. Should subsidies be *ad valorem* or per-unit?

Generally speaking, both *ad valorem* and per-unit subsidies can be found. In France, the subsidy portfolio was initially dominated by the *ad valorem* regime, owing to the central role played by the CITE program. As the CEE program grew bigger and the CITE program was replaced by MPR, the per-unit regime became the dominant one. Which one is best? The answer is trivial under perfect competition – for a given per-unit subsidy, it is always possible to find an *ad valorem* rate that generates the same effect, such that the two regimes are equivalent. It is more ambiguous under imperfect competition, which is an important characteristic of energy efficiency markets (Fischer, 2005). In France, there is indeed evidence that market concentration is substantially higher in the appliance and energy retrofit industries than in other industries (Carbonnier, 2007). In this context, the French Anti-trust authority has raised suspicion of collusive practices in the heating, air conditioning and hot water industries, at both the manufacturing and retail levels (Conseil de la Concurrence, 2006).

Theoretical research into the relative merits of *ad valorem* and per-unit subsidies under imperfect competition points to a clear superiority of the latter, for different reasons (Nauleau *et al.,* 2015). In the simplest framework where a monopolist is selling a single energy efficient product, ad valorem subsidies entail higher public spending since, compared to per-unit subsidies, they need to make up for the lower product price to which the subsidy rate applies. In the richer framework of a multi-product monopolist selling two goods, a high-end product of high energy efficiency and a low-end product of low energy efficiency, the inability of the monopolist to observe the preference of the buyer for the high- or low-end product induces it to restrict the quality of the low-end product to make sure the high-end consumer buys the high-end product. Through their action on prices again, *ad valorem* subsidies only exacerbate this problem, which is not the case with per-unit subsidies.

4.2. The more finely targeted the better?

Existing subsidy programs increasingly target low-income households. In France, this was the case when the low-income sub-obligation was introduced in the CEE program in 2016 and the MPR program superseded the non-targeted CITE program in 2020. This regulatory change was driven by and large out of necessity, as imposing income restrictions is an easy way to reduce overall spending in tense economic times. But this can also be seen as a win-win intervention reducing fuel poverty while increasing allocative efficiency. This is due to the correlation that is often observed between energy efficient housing and household income (Chan and Globus-Harris, 2025). In this context, renovating the least efficient homes mostly benefits low-income households while making the most out of public spending.

This insight has been confirmed in France, where both microsimulation works (Giraudet *et al.,* 2021) and the joint evaluation of multiple programs (Chlond *et al.,* 2023) have showed that low-income targeting increased the leverage of subsidies. Looking at the low-income sub-obligation in the CEE program, Darmais *et al.* (2024) find that it effectively reduced the households' vulnerability to energy price increase – a side effect of the CEE program we will return to. Against this background, it should be reminded that Eryzhenskiy *et al.* (2023) find that the EPTZ mostly benefited low-income homeowners despite the fact that it was open to all. This goes to suggest that imposing specific provisions is not a necessary condition for subsidies to benefit low-income households.

4.3. Do utility-sponsored programs perform better than publicly-funded ones?

While most energy efficiency subsidy programs are publicly funded, they coexist in many countries with utility-sponsored programs. The latter are usually implemented to comply with an energy efficiency obligation, known in North America as Demand-Side Management (Berry, 1984; Joskow and Marron, 1992; Wirl, 2000; Auffhammer *et al.,* 2008) and in Europe as White Certificate programs (Bertoldi *et al.,* 2010; Giraudet *et al.,* 2012; Rosenow *et al.,* 2019). Implemented in 2006, the French CEE program has grown to become the most important utility-funded program. Its interaction with several other publicly funded programs makes it an ideal case study to compare the merits of the two systems.

Just like the targeting discussed in the previous section is motivated by reducing public spending, so too is the case with delegating part of the energy saving effort to utilities. This is only a money transfer from tax payers (who pay for publicly funded programs) to rate payers, however, since utilities are allowed to pass-through compliance costs onto their retail prices. This mechanism makes utility-sponsored programs a hybrid instrument between an energy efficiency subsidy and an energy tax. On the one hand, this allows the same amount of energy to be saved with lower price variations than under a pure tax or a pure subsidy, thus making the instrument politically more palatable (Giraudet and Quirion, 2008). On the other hand, it raises equity issues, as subsidies are only granted to a few beneficiaries while being paid by all energy end-users. Such a regressive effect can however be overcome by adding provisions for low-income households (Darmais *et al.,* 2024).

Alongside these practical considerations, as is again the case with targeting, the delegation of energy savings can also be motivated by allocative considerations. Energy utilities are indeed thought to possess private information about end-use patterns, which puts them in an ideal position to identify the best energy saving opportunities. Imposing an energy efficiency obligation on them is thus expected to leverage this informational advantage and deliver energy savings more cost-effectively than would the government. While free competition among obligated parties might encourage them to promote energy savings by their competitor's customers, thereby discarding the intended mechanism, this threat is mitigated by the trading provision, which restores incentives to target the most cost-effective options (Giraudet *et al.,* 2020).

Does this work in practice? In their assessment of the third phase of the program, Aja and Giraudet (2025) find that the impact of the program, despite being low overall due to a low white certificate price, was nevertheless concentrated on a handful measures that rank pretty high in the cost-effectiveness merit order – attic, wall and floor insulation – and more so than what the publicly-funded CITE program produced. The authors interpret this outcome as evidence that the program was at least qualitatively effective at identifying the best renovation opportunities. One could expect that the subsequent tightening of the target would increase the white certificate price, hence subsidy amounts, thereby making the program fully additional, both quantitatively and qualitatively. The fourth phase of the program that started in 2018 fulfills the first part of the expectation but casts doubt on the second. The tightening of the target did cause prices to soar. Prompted to act by energy suppliers, the government responded by introducing a bonus system boosting earned certificates. This intervention had the expected effect of containing the price increase. Meanwhile, it changed the pattern of actions in a way that closely matched the pattern of bonuses designed by the government. This indicates that the role of the government was more important in steering actions than that of energy suppliers. This does not mean that the program was quantitatively ineffective – it was, in particular when it comes to job creation (Cohen *et al.,* 2024). But this essentially resulted from a government impetus, rather than from energy suppliers leveraging private information. Taken together, these results seriously challenge the information leverage hypothesis and hence the added value of utility-sponsored programs compared to publicly funded ones.

4.4. Do local programs perform better than national programs?

Subsidy programs are typically implemented at the national or state level – *e.g.,* Italy, France, Denmark, Germany, the UK, Massachusetts, Connecticut – and, to a lesser extent, at local or municipal levels – *e.g.,* Baltimore, Chicago, Detroit, Portland (Kerr, 2020). This raises the question of which level is the most appropriate – national or local? One could argue that industry stimuli, which are integral part of the motivation of subsidy programs, are most effective the wider they are, thus enabling economies of scale. On the other hand, home renovation essentially relies on local contractors. It is moreover a tailored technology akin to a credence good (Giraudet, 2020). Identifying the most cost-effective opportunities thus requires a good understanding of the housing stock, which is arguably best achieved by local agencies. The answer to the scale question is therefore ambiguous. France could be a good candidate to study it, owing to a plethora of local programs (560). However, these are much less well documented than their national counterparts. We thus provide hints based on the Essonnian PEL program. As discussed previously in various sections, the program had a significant effect on both natural gas consumption – an 8% reduction – and employment – 20 jobs created in the renovation industry per million euro spent. These results compare quite favorably to national programs – the CEE in particular. Interestingly, we find that, compared to the MPR subsidies granted in the same department, the PEL program had a stronger effect on hiring Essonnian firms. This indicates that its benefits are mostly retained locally. This could be due to a stronger involvement of local agencies in advertising for the program, in turn due to a closer alignment of incentives between public spending and the revenue from corporate taxes, which accrues locally.

5. CONCLUSION

This review of subsidy programs for home energy retrofits, focused on the French context, delivers the following insights. Overall, they are effective at increasing investment, however with a large number of infra-marginal participants, which probably is the reason for their relatively low marginal value of public funds. It should however be noted that energy efficiency subsidies can address several market and behavioral frictions at the same time, and failure to recognize this may lead to an underestimation of their benefits. In terms of energy savings, with a performance gap of about 50%, subsidies do just as well as non-subsidized energy efficiency investment.

Beyond these general conclusions, the comparison of different programs has shed light on which design features perform best. Per-unit subsidies should be preferred to ad valorem ones, due to the lower price distortions they generate under imperfect competition. Targeting subsidies to low-income households is a win-win approach that reduces fuel poverty while increasing the efficiency of public spending. While evidence needs to be further corroborated, local programs exhibit good properties, which is consistent with the essentially local nature of energy efficiency markets. This calls for a stronger involvement of local agencies in administrating subsidy programs. Lastly, utility-sponsored programs do not seem to add much value to public spending. This calls for merging the two systems, such as into the sort of "one-stop shop" promoted by the European Commission (Pardalis *et al.,* 2025). In this case, the same amount of private funding would be requested, but instead of having energy suppliers granting subsidies themselves, they would contribute the same amount to a public-private fund which would redistribute subsidies.

Some important questions inherent in subsidy programs remain unanswered, thus providing promising avenues for further research. One is to what degree subsidies increase the price of home energy retrofits in the field. Another one is whether energy efficiency subsidies encourage technological change, which in turn determines whether they should be temporary or permanent. Preliminary evidence suggests this is not the case (Hahn *et al.,* 2024), thus calling for rather permanent subsidies. Lastly, energy efficiency subsidy programs are known to entail administrative complexities. The extent to which this affects participation is an open question. Preliminary research suggests it can be a big hurdle, which however can be easily overcome with careful policy changes (Chlond *et al.,* 2025).

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Sistema de Certificados de Ahorro Energético (CAE), el motor que ya impulsa la transformación energética en España

*Jon Macías Santiago**

Resumen

La política climática marcada por Europa para 2030, abarca objetivos medioambientales, energéticos y climáticos, los cuales se pueden resumir en tres ejes:

- *Objetivos climáticos para 2030:* Reducir las emisiones de gases de efecto invernadero (GEI) en la Unión Europea (UE) en un 55 % con respecto a los niveles de 1990 para el año 2030.
- *Objetivos de eficiencia energética:* La UE ha acordado un ambicioso objetivo de eficiencia energética, que consiste en reducir el consumo de energía final en al menos un 11,7 % en comparación con las previsiones sobre el consumo de energía esperado para 2030.
- *Objetivos para las energías renovables:* La UE pretende acelerar la adopción de energías renovables con el objetivo de alcanzar una reducción de las emisiones netas de gases de efecto invernadero en al menos un 55 % para el año 2030.

Para abordar estos cambios, cada país lo enfoca de manera diferente según su dependencia energética y el *mix* de consumo. En el caso de España, se ha optado por cumplir los objetivos de eficiencia energética a través de los Certificados de Ahorro Energético (CAEs).

La eficiencia energética ha dejado de ser una opción para convertirse en una necesidad estratégica. Implica la puesta en marcha de mecanismos de apoyo económico y financiero, asistencia técnica, formación e información, y otras medidas que mejoran la eficiencia energética en los diferentes sectores, ayudando a alcanzar el objetivo de ahorro establecido.

En esta nueva realidad, el sistema de CAEs se ha consolidado como una de las herramientas más prometedoras para impulsar la transformación energética en nuestro país.

Aunque el sistema de CAEs en España todavía se encuentra en una fase inicial, su impacto ya es evidente. Ha permitido a numerosas empresas, administraciones públicas y particulares llevar a cabo proyectos de eficiencia energética, reduciendo tanto el consumo como las emisiones. La clave de este éxito reside en la monetización de los ahorros obtenidos, lo que ha mejorado significativamente la rentabilidad de estas iniciativas. Como resultado, cada vez más organizaciones optan por este modelo.

Los Certificados de Ahorro Energético están transformando la manera en que las empresas abordan la sostenibilidad, al combinar beneficios económicos con un impacto positivo en los estándares *ESG*. Estas herramientas

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claves no solo promueven la eficiencia energética, sino que también refuerzan la transparencia y la responsabilidad ambiental en los informes corporativos.

En un entorno empresarial donde la sostenibilidad y la responsabilidad social son cada vez más cruciales para la estrategia corporativa, los CAEs se destacan como una herramienta esencial para ayudar a las empresas a cumplir con los estándares *ESG* (ambientales, sociales y de gobernanza). Estos certificados tienen un impacto positivo en la mejora de los informes *ESG*, promoviendo una mayor transparencia y eficiencia en el camino hacia la sostenibilidad, con indicadores cuantitativos y objetivos.

- **CUMPLIMIENTO NORMATIVO Y BENEFICIOS *ESG***

Gracias a iniciativas como el sistema CAEs, regulado por el Real Decreto 36/2023, de 24 de enero, se desarrolla reglamentariamente el artículo 71.2 de la Ley 18/2014, de 15 de octubre, que posibilita establecer un mecanismo para acreditar el ahorro anual de energía mediante la presentación de CAEs.

Las empresas encuentran en los CAEs una alternativa eficaz para cumplir con las obligaciones impuestas por la normativa europea y nacional. Estas acciones no solo optimizan los recursos energéticos, sino que también aseguran un mejor desempeño en las auditorías de sostenibilidad y en la presentación de información no financiera exigida por las regulaciones europeas y la taxonomía verde.

La Unión Europea ha fijado el ambicioso objetivo de reducir las emisiones GEI en un 55 % para 2030. Los CAEs son una herramienta clave para alcanzar este objetivo, ya que incentivan a las empresas a invertir en eficiencia energética y en la descarbonización.

- **¿QUÉ ES UN CERTIFICADO DE AHORRO ENERGÉTICO CAE?**

Para comprender mejor, es importante recordar ¿qué es el Fondo Nacional de Eficiencia Energética (FNEE)?

Este fondo se constituyó en octubre de 2014 y tiene como objetivo financiar iniciativas nacionales de eficiencia energética, en cumplimiento del artículo 20 de la directiva europea.

El FNEE está adscrito al Ministerio para la Transición Ecológica y el Reto Demográfico, a través de la Secretaría de Estado de Energía, y es gestionado por el Instituto para la Diversificación y Ahorro de la Energía (IDAE).

En 2024, dicho fondo alcanzó un importe de más de 784 millones de euros. Los CAEs son el mecanismo mediante el cual las empresas energéticas pueden sustituir sus aportaciones económicas al FNEE, optando por los CAE. Se estima que en 2027 la aportación combinada entre el FNEE y los CAEs serán de aproximadamente 2.100 millones de euros.

Un CAE es un documento electrónico que asegura que, tras implementar una medida de eficiencia energética (como el cambio de luminarias a tecnología LED, la instalación de variadores de velocidad, o la mejora de la envolvente), se ha logrado un ahorro de energía equivalente a 1 kWh. Por ejemplo, si se realiza una acción que genera un ahorro anual de 500 kWh, se podrán obtener 500 CAEs.

Este activo, una vez acreditado por la administración correspondiente de cada comunidad autónoma, puede ser comprado y vendido, y su valor se negocia en el mercado. De este modo, los CAEs actúan como un incentivo para invertir en eficiencia energética y mejoran el rendimiento de dichas inversiones. Básicamente, "te pagan por ahorrar".

Los CAE son compatibles con cualquier ayuda o subvención que reciba un proyecto, excepto si su origen es el Fondo Nacional de Eficiencia Energética (FNEE), del cual son una alternativa para las empresas. Como novedad, en los tres primeros años del Sistema CAEs (2023, 2024 y 2025), los sujetos obligados podrán liquidar sus obligaciones vía CAEs hasta el 1 de marzo del año siguiente, lo cual puede provocar casos de CAEs certificados, pero no liquidados, evidenciando que el ahorro energético es mayor de lo visualizado.

Se pueden obtener CAEs tanto por acciones estándar como por acciones singulares. Las acciones estándar son aquellas que, mediante una ficha, simplifican la documentación y los criterios de validación. Actualmente, el catálogo consta de 114 fichas. Las acciones singulares son aquellas que, por su complejidad o volumen, no se pueden estandarizar y se tratan de manera específica.

Los CAEs tienen una validez de tres años, contados desde la fecha en la que se finalizó la ejecución de la acción generadora del ahorro de energía, o hasta el 31 de diciembre de 2030. Este también es el plazo máximo para registrar y liquidar los CAEs tras ejecutar la acción.

Este instrumento permite monetizar los ahorros energéticos, recuperando parte del coste de las inversiones en eficiencia energética, ya que el usuario final podrá recibir una contraprestación si vende los ahorros obtenidos para su posterior certificación mediante el Sistema de CAEs.

El modelo CAE permite monetizar los ahorros y recibir los incentivos económicos prácticamente al momento de ejecutar los proyectos. La empresa se convierte en propietaria de los ahorros, pudiendo venderlos y convertirlos en CAEs a través de la venta directa a un *sujeto obligado* o a través de la figura del *sujeto delegado*, empresas expertas que asesoran y ayudan a otras compañías a optimizar y rentabilizar sus inversiones en eficiencia energética, actuando como intermediarios para la venta de los Certificados de Ahorro Energético (CAEs) a los sujetos obligados por la normativa nacional.

• ¿QUÉ AGENTES INTERVIENEN?

El actor principal en el sistema CAEs es el usuario, quien ha realizado la inversión en una acción de eficiencia energética que puede generar ahorros convertibles en CAEs. Estos ahorros pueden ser transferidos a un tercero a cambio de una compensación.

Además, intervienen varios actores secundarios:

- Sujetos obligados. Son las empresas energéticas, como comercializadoras de gas y electricidad y operadores al por mayor de productos petrolíferos y GLP, que deben lograr una cantidad específica de ahorro energético al año. Estas empresas pueden cumplir con su obligación ya sea pagando al Fondo Nacional de Eficiencia Energética (FNEE), gestionado por el Instituto para la Diversificación y Ahorro de la Energía (IDAE), o mediante el sistema de los CAEs.
    - Entre las firmas obligadas se encuentran marcas reconocidas como Iberdrola, Cepsa, Repsol, EDP, Naturgy, y hasta un total de 706 compañías. En 2025, estas empresas deberán aportar colectivamente 1.100 millones de euros al FNEE. Sin embargo, esta cantidad se reduce a 165 millones si aporta el máximo permitido del 85 % mediante Certificados de Ahorro Energético (CAEs). Esto significa que estos

agentes pueden optar por pagar el precio máximo (FNEE) o liquidar los CAEs, cuyo valor siempre será inferior a dicho importe.

- Entre los sujetos obligados, la aportación más significativa proviene de Repsol, con cerca de 245 millones sin CAEs entre todas sus empresas. Le siguen Endesa con 131 millones, Moeve (anteriormente Cepsa) con 117 millones, Iberdrola con aproximadamente 77 millones y BP con casi 50 millones.

- Sujetos delegados. Son empresas que ayudan tanto a los sujetos obligados a cumplir sus compromisos, como a las empresas propietarias de ahorro a rentabilizarlos mediante la emisión y venta de CAEs. Están oficialmente acreditados para certificar los ahorros de empresas y particulares. Para ello, suscriben el "Convenio CAE" con las empresas propietarias del ahorro, regulando los servicios a prestar, como la conversión del ahorro en CAEs y la compensación.

- Verificador del ahorro energético. Antes de solicitar el CAEs ante los gestores autonómicos y el MITECO, se recopila toda la información y se realiza la verificación a cargo de un certificador acreditado por la Entidad Nacional de Acreditación (ENAC). Con el dictamen favorable de este verificador, se presenta la solicitud para la emisión del CAEs y su posterior venta a través de un sujeto delegado.

- MITECO y gestores autonómicos. Los gestores autonómicos y el Ministerio para la Transición Ecológica y el Reto Demográfico emiten los Certificados de Ahorro Energético tras recibir una solicitud y documentación revisada y validada por un verificador autorizado. Con el Certificado de Ahorro Energético en su poder, las empresas pueden empezar a rentabilizarlo negociando su venta a los sujetos obligados a través de un sujeto delegado.

Palabras clave: Certificados de Ahorro Energético, eficiencia energética, España.

1. PROCESOS DEL SISTEMA DE CAEs MERCADO PRIMARIO

La hoja de ruta para transformar los ahorros energéticos en CAEs comienza con la ejecución de la actuación generadora de ahorro y beneficia a todos los sectores (agrario, industrial, terciario, residencial, transporte, etc.).

Su ejecución debe haber comenzado después del 26 de enero de 2023, que es la fecha de entrada en vigor del RD 36/2023.

Además de ejecutar y poner en funcionamiento la actuación de ahorro, se debe recopilar la información relativa a la misma: facturas, reportajes fotográficos, certificados de instaladores, actas de puesta en marcha, etc. También, se deben contabilizar los kWh ahorrados, que se transformarán en CAEs mediante las fórmulas que aparecen en las fichas o mediante un método que permita al sujeto delegado verificar el ahorro.

Hay dos formas de contabilizar ahorros en función del tipo de actuación:

1. Actuaciones estandarizadas. Están publicadas en unas fichas que constituyen un catálogo. Tienen una metodología sencilla de cálculo para cada actuación y actualmente

hay 114 fichas que simplifican la verificación con base en unas fórmulas en función de las medidas adoptadas. Se pueden enumerar múltiples ejemplos de ahorro energético como puede ser un cambio de envolvente en edificios, unas pantallas térmicas en invernaderos, sustitución de un compresor en una instalación frigorífica, sustitución de una caldera de combustión por una bomba de calor, implementación de variadores de velocidad, adquisición de lavadoras, lavavajillas de alta eficiencia, vehículos compartidos en trayectos largos, etcétera.

2. Actuaciones singulares. Son aquellas actuaciones que no entran en catálogo. Aquí se complica la contabilización del ahorro. Se utilizan protocolos internacionales de medición y verificación como es el IPMVP (Protocolo Internacional de Medida y Verificación del Ahorro Energético). Está desarrollado por EVO (Efficiency Valuation Organization) y es un proceso que consiste en utilizar la medida y verificación, de forma fiable, del ahorro real generado en una instalación dentro de un programa de gestión de la energía. Siempre hay que establecer una Línea Base Energética anterior a la actuación y se normaliza en función de las variables que resulten significativas para el consumo que se esté midiendo. Por ejemplo, los kwh de consumo de un horno eléctrico se normalizan en función de la producción y la temperatura, si es que resultan variables significativas. Después de la puesta en marcha de la actuación se realiza un periodo de medición demostrativo de los ahorros.

Con los ahorros calculados y la actuación puesta en marcha, se debe pasar por una verificación, que debe ejecutar una entidad habilitada a tal efecto.

Se trata de una evaluación de la veracidad y verosimilitud del cálculo de ahorros declarado por el solicitante, de la actuación ejecutada y de la documentación que se presente. Solamente un sujeto obligado o un sujeto delegado pueden solicitar este trabajo.

El equipo verificador realiza una primera etapa de Evaluación Documental y, como mínimo, se revisa la documentación requerida en fichas de catálogo, el proyecto en actuaciones singulares y el Convenio y los cálculos de ahorro. Se evalúa el riesgo de la verificación a realizar, y se emite un Plan de Verificación y Muestreo.

Se acuerda una fecha con el cliente y se realiza la verificación propiamente dicha, en la que se comprueban al detalle todos los cálculos que llevan a la cantidad de ahorro anual de energía, y el cumplimiento de los requisitos de la información y documentación aportada conforme al catálogo de fichas o la reglamentación. El proceso de verificación puede incluir visita a las instalaciones para las comprobaciones pertinentes.

Se constata la fiabilidad de las lecturas de los equipos de medición que aportan datos al cálculo. Finalmente, el verificador emite un informe y un dictamen de verificación. El dictamen puede ser “Favorable”, “Favorable con inexactitudes no importantes” o “Desfavorable con inexactitudes importantes”, en caso de rebasar un nivel de materialidad, que para actuaciones singulares están en el 2 %.

Con este informe y dictamen, el sujeto delegado u obligado puede solicitar el registro de los kWh verificados en forma de Certificados de Ahorro Energético en la comunidad autónoma correspondiente.

2. MERCADO SECUNDARIO

Una vez que los Certificados de Ahorro Energético (CAEs) pasan el filtro de la comunidad autónoma y del Ministerio de Transición Ecológica y Reto Demográfico, son registrados y se pueden comercializar en el mercado secundario. En este mercado, los CAEs se pueden comprar, vender o liquidar frente a las obligaciones anuales de contribución de los sujetos obligados al Fondo Nacional de Eficiencia Energética. Se dispone de tres años para liquidar los CAEs desde el inicio de la actuación, y solo pueden participar en este mercado los sujetos obligados y delegados.

El sistema de CAEs va más allá de ser un mero instrumento financiero. En un contexto de volatilidad en los precios de la energía, las organizaciones que invierten en eficiencia energética logran mitigar riesgos, reducir su dependencia de fuentes externas y mejorar su competitividad. Al mismo tiempo, este sistema favorece la innovación y la adopción de tecnologías limpias, sentando las bases para un cambio estructural en la gestión de la energía en España.

3. IMPACTO ECONÓMICO DEL SISTEMA

El primer balance de implementación del Sistema de Certificados de Ahorro Energético (CAEs), desplegado por el Ministerio para la Transición Ecológica y el Reto Demográfico, muestra que en 2024 se realizaron más de 1.200 actuaciones de eficiencia energética. Este esfuerzo ha generado un ahorro significativo tanto para los consumidores como para la industria, en términos energéticos y económicos.

Estas actividades han permitido ahorrar anualmente 2 teravatio-hora (TWh) de energía final, lo cual equivale al consumo eléctrico de un mes en la Comunidad de Madrid. Además, se ha evitado la emisión de aproximadamente 500.000 toneladas de CO_2, lo que representa alrededor del 1 % de las emisiones anuales de la industria nacional.

El ahorro en la factura eléctrica es uno de los beneficios de estas medidas, pero también cabe destacar los ingresos adicionales obtenidos por la venta de ahorros. Hasta la fecha, estos ingresos se estiman en unos 230 millones de euros, proporcionando un incentivo adicional para la adopción de prácticas de eficiencia energética.

Ahorro energético y económico para familias e industria

En 2024, el Sistema de CAEs registró más de 1.200 actuaciones de mejora de la eficiencia energética, agrupadas en 755 solicitudes. De estas, un 88 % ya han recibido resolución favorable, demostrando así su utilidad como impulsor para la comercialización de productos y servicios energéticos destinados a pequeños consumidores, empresas y grandes industrias. Además, ha fomentado un ecosistema de colaboración y crecimiento con el tejido empresarial del sector energético.

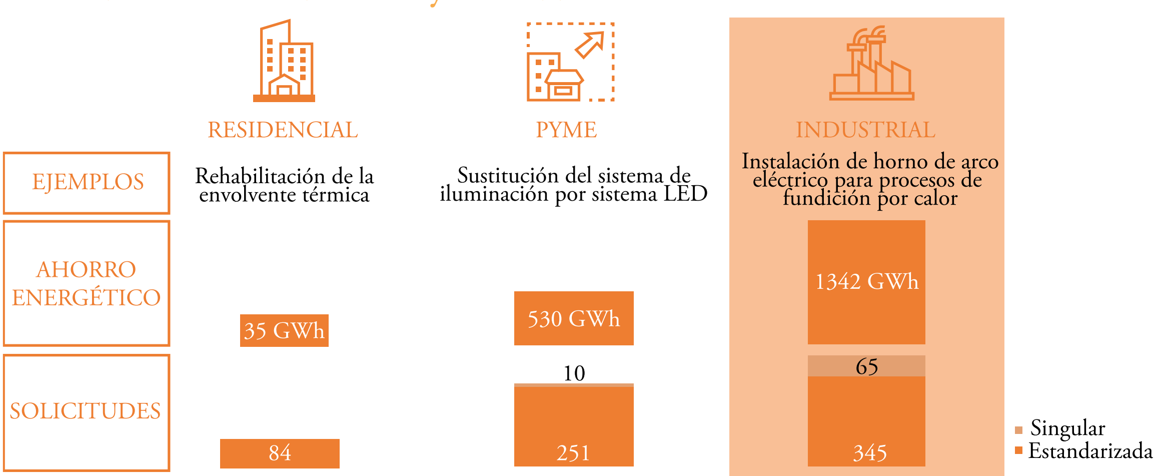
El 68 % de los ahorros certificados provienen de 78 actuaciones singulares, principalmente en el sector industrial, lo que ha supuesto un ahorro conjunto de 1,3 TWh (1.300 GWh). Entre las actuaciones más destacadas se encuentran la optimización de hornos industriales y la recuperación de energía en procesos de alta intensidad.

Analizando los datos por sectores, el sector industrial es el más beneficiado con el 68 % de los ahorros, seguido por el transporte con un 23,4 % y finalmente el sector terciario con un 6,5 % y el residencial con un 2,2 %.

Hasta el 31 de enero de 2025, los propietarios iniciales del ahorro han percibido entre 115 y 140 euros por MWh ahorrado, lo que ha permitido “desempolvar” proyectos previamente analizados que sin este mecanismo no se habrían abordado.

Figura 1

Distribución sectorial de ahorro y solicitudes



El Sistema ha incrementado la actividad de 500 proveedores de productos y servicios de eficiencia energética, incluyendo fabricantes de equipos, distribuidores e ingenierías, quienes han implementado estas actuaciones. Además, 46 sujetos delegados y 54 sujetos obligados se han incorporado al Sistema, de los cuales 33 aportan directamente al Fondo Nacional de Eficiencia Energética, verificando el ahorro de sus propias actuaciones.

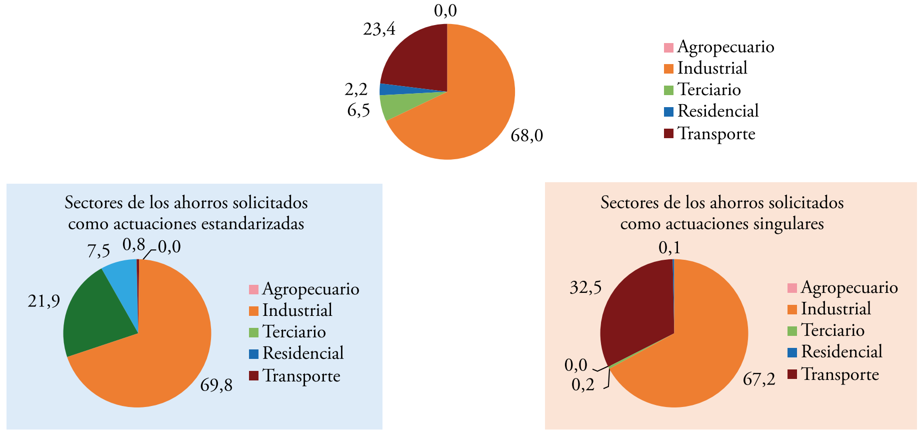
La industria impulsa su competitividad y en 2024 copa el 70 % de ahorro.

El 54 % de las solicitudes de verificación de ahorros, 410 peticiones, provinieron de compañías del sector industrial, que han conseguido una reducción del consumo de energía de 1.342 GWh (70,4 % del total), según los datos aportados por MITECO.

A continuación, se sitúan el sector terciario, con el 35 % de las actuaciones (256 en total) y un ahorro de 530 GWh, equivalente a el 27,8 %; y el residencial, con 84 solicitudes y 35 GWh de reducción del consumo.

Figura 2

Actuaciones por sectores de ahorros



En cuanto a la distribución territorial, todas las comunidades y ciudades autónomas han presentado solicitudes, a excepción de Melilla. Madrid es la región con el mayor número de actuaciones de eficiencia energética, concentrando un 20 % del total, seguida de Cataluña (19 %), Comunidad Valenciana (12 %) y Andalucía (10 %).

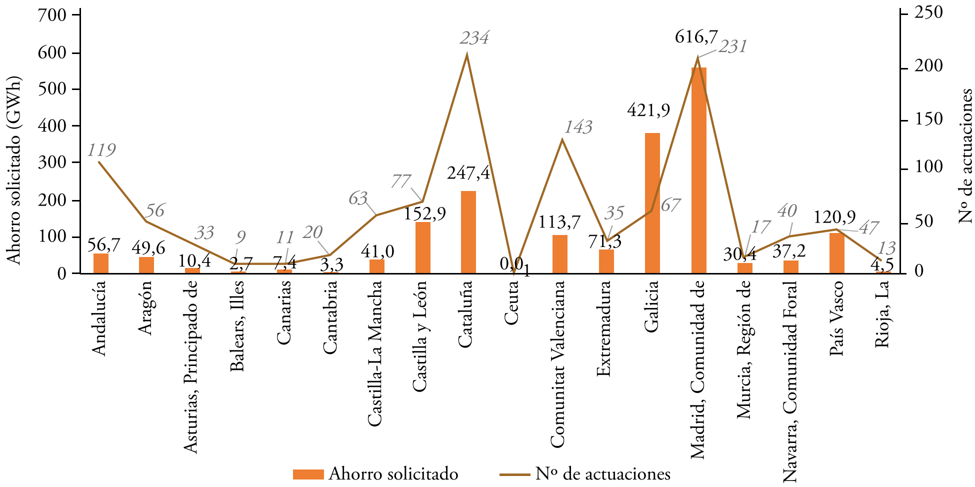
Entre las actuaciones de eficiencia energética implementadas en 2024, destacan especialmente las 78 actuaciones singulares, impulsadas principalmente desde el entorno industrial, con un ahorro conjunto de más de 1,3 TWh, representando el 68 % del total. La optimización de hornos industriales y la recuperación de energía en procesos de alta intensidad son dos ejemplos clave de cómo los CAEs pueden catalizar inversiones significativas.

Actualmente, se ha puesto en Consulta Pública Previa la propuesta de Orden para implementar un sistema de subastas de ahorro energético, que tiene como objetivo reforzar los incentivos para que las medidas de eficiencia energética mejoren la competitividad empresarial y la calidad de vida de los consumidores.

La consulta, que se cerró el 28 de febrero de 2025, ofreció a los agentes la oportunidad de aportar sus puntos de vista sobre la necesidad de establecer criterios para segmentar las necesidades de ahorro por actuación, qué medidas deberían contemplarse para asegurar la competencia efectiva en las subastas y qué consideraciones deberían tenerse en cuenta en la futura regulación de las subastas de necesidades de ahorro energético.

Figura 3

Distribución territorial de solicitudes



4. EJEMPLOS DE CERTIFICADOS EMITIDOS EN EL 2024 EN EL SECTOR SANITARIO, TERCIARIO E INDUSTRIAL

Podemos concretar ejemplos en diferentes sectores (sanitario, terciario, hotelero e industrial), algunos de los cuales pueden solaparse en un mismo cliente.

En el sector terciario, lo primero que debemos abordar es la medición del consumo de edificios. Lo que no se mide, no se puede mejorar. Por eso, implementar sistemas de monitorización es una de las primeras medidas necesarias para establecer un plan de descarbonización eficiente.

Uno de estos sistemas es el *Building Management System* (*BMS*), que administra y monitoriza todos los sistemas del edificio, incluidos el eléctrico, el HVAC, la producción de energía renovable y el consumo de electricidad y gas.

Los *BMS* son grandes beneficiarios de los Certificados de Ahorro Energético (CAEs), y en un hospital de Madrid, la implementación de dicho sistema supuso un ahorro térmico y eléctrico de 1.500.000 kWh. La contraprestación de los CAEs fue de más del 50 % de la inversión, y el edificio alcanzó la clase A de eficiencia energética.

El turismo juega un papel fundamental en la economía española. En los últimos años, el país se ha convertido en uno de los destinos turísticos más importantes a nivel mundial, gracias en parte a la industria hotelera. En diciembre de 2024, había registradas alrededor de 12.430 empresas con más de 17.800 establecimientos en todo el territorio nacional, y están en proceso de descarbonización porque los clientes reclaman hoteles sostenibles.

Además de beneficiarse de los *BMS* para medir y actuar, una medida muy bonificada es la electrificación de la demanda, que implica el cambio de combustibles fósiles por consumo eléctrico. Una solución es reemplazar la caldera de gas/gasóleo por una bomba de calor/aerotermia. Por ejemplo, un hotel de una cadena muy conocida en Palma de Mallorca eliminó las calderas y enfriadoras existentes y las reemplazó por bombas de calor. Esta medida sin CAEs se rentabiliza en 7-8 años, y con los CAEs (que generaron 1.000.000 kWh) se rentabiliza en 4 años.

En el sector industrial, un ejemplo es la planta de fabricación de automóviles ubicada en Valladolid, donde se cambió la iluminación por tecnología LED. Esta medida de eficiencia generó ahorros desde 300.000 kWh hasta más de 1 GWh y se realizó mediante fichas estándar.

5. PRIMEROS PASOS MUY PROMETEDORES, PERO TENEMOS QUE SEGUIR EVOLUCIONANDO

Es un mecanismo que recién ha nacido y, aunque ya ha comenzado a dar sus primeros pasos, es necesario que avance con firmeza. Hay áreas de mejora que podemos y debemos abordar.

- Creación de plataformas aglutinadoras. Estas plataformas podrían agrupar pequeñas medidas y permitir que los particulares con proyectos modestos puedan beneficiarse del sistema. Ejemplos de estas medidas incluyen cambios de ventana, envolventes, sustitución de calderas de gas por bombas de calor, entre otros.

- Implementación del sistema de CAEs en el sector público. Es preocupante que más del 40 % del alumbrado público aún no sea LED, especialmente cuando las ciudades tienen la iluminación encendida entre 10 y 14 horas diarias, los 365 días del año. Esta inversión se rentabiliza en menos de un año. El sector público debe convertirse en el modelo ejemplar en cuanto a eficiencia energética.

- Comunicación y divulgación. Es esencial dedicar recursos para informar y divulgar esta nueva alternativa. El desconocimiento sobre el sistema de CAEs es muy alto.

- Compatibilidad de subvenciones. No tiene sentido que los CAEs sean incompatibles con otras subvenciones, siempre y cuando no provengan del FNEE. El objetivo nacional es alcanzar la descarbonización más rápidamente, y la compatibilidad de subvenciones aceleraría el interés y la implementación de medidas de eficiencia energética.

- Multiplicadores de competitividad. Implementar multiplicadores en sectores o segmentos del mercado es fundamental para mejorar la competitividad industrial y crear puestos de trabajo de calidad y estables.

6. EL FUTURO DE LOS CAEs EN ESPAÑA

Los primeros y positivos resultados obtenidos hasta ahora demuestran que el sistema de CAE ha llegado para quedarse. Su capacidad para generar ahorros, incentivar la inversión en eficiencia a medio plazo y contribuir a la sostenibilidad lo convierte en un pilar clave en la estrategia energética del país.

Sin embargo, para que este sistema despliegue todo su potencial, es fundamental que tanto el sector público como el privado sigan apostando por su desarrollo. La colaboración entre ambos sectores será crucial para consolidar el sistema de CAE como un mecanismo estable y atractivo a largo plazo. Si España quiere avanzar de manera decidida hacia un modelo energético más eficiente y sostenible, el sistema de CAE representa una de las herramientas más prometedoras para lograrlo.

Para el año 2025, se ha publicado la Orden TED/197/2025 a principios de marzo, en la que se establece un objetivo de ahorro de energía final del Sistema Nacional de Obligaciones de Eficiencia Energética de 500 ktep o 5.815 GWh. La equivalencia financiera para el año 2025 se establece en 2,20 millones de euros por ktep ahorrado, lo que equivale a 189.165,95 euros por GWh ahorrado.

La previsión de los datos aportados es que en 2026 las obligaciones totales de ahorro de energía final para los sujetos obligados sean de 9.420 GWh y que el porcentaje anual máximo de obligaciones de ahorro mediante CAEs sea del 90 %.

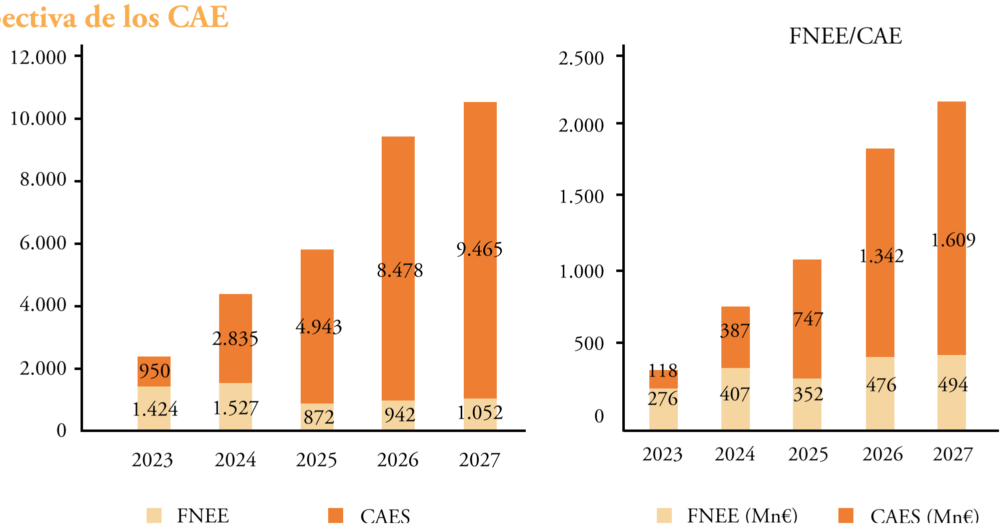
El sistema durará al menos hasta 2030, proporcionando fondos para eficiencia energética de forma estable y ágil. Las obligaciones de ahorro son crecientes año a año: 4.362 GWh en 2024, 5.815 GWh en 2025 y 9.420 GWh en 2026. La proporción de peso de los CAEs también aumenta progresivamente. De los 5.815 GWh de 2025, los CAE pueden representar el 85 %, es decir, 4.652 GWh.

Tabla 1
Obligaciones de ahorro

Año	GWh	Max. Obligac. CAE (%)
2023	2.374	40
2024	4.299	65
2025	5.815	85
2026	9.420	90
2027	10.517	90

Y con estos datos, la perspectiva de los siguientes años en GW/h y en euros es esta:

Figura 4
Perspectiva de los CAE



Es un mercado creciente que en 2027 será de 2.027 millones de euros, de los cuales se pueden liquidar con certificados de ahorro energético un máximo de 1.609 millones de euros.

Si estimamos que los CAEs representan un 25 % de la inversión, puede ser un mercado relevante para la economía española, con una movilización en 2027 de 6.400 millones de inversión en actuaciones de Eficiencia Energética.

Tabla 2
Inversión Eficiencia Energética

Año	Inversión Efic. Energét. (Mn €)
2023	473
2024	1.548
2025	2.989
2026	5.367
2027	6.436

7. ¿ÉPOCA DE CAMBIOS Ó CAMBIO DE ÉPOCA?

La llegada del sistema de CAEs ha marcado un auténtico cambio de época en la política energética del país. En el corto plazo, ha fomentado una mayor concienciación sobre la importancia del ahorro energético en sectores clave como la industria y la construcción. Las empresas, cada vez más, entienden que reducir el consumo no solo es beneficioso para el medio ambiente y la reputación, sino que también genera beneficios económicos tangibles

El verdadero impacto del sistema de CAEs se observará a largo plazo. A medida que su adopción se extienda, este sistema acelerará considerablemente la descarbonización de la economía española. Además, al incentivar la inversión en medidas de eficiencia, los CAEs impulsan el desarrollo y la implementación de tecnologías avanzadas, desde sistemas inteligentes de gestión energética hasta mejoras en la infraestructura de edificios e industrias. Esto resultará en una significativa reducción de las emisiones de CO_2 y en un alineamiento más sólido con los objetivos de sostenibilidad fijados por la Unión Europea.

Es relevante mencionar que, en contraste con el sistema actual de subvenciones, que depende de la administración y tiene plazos de pago largos (entre 16 y 24 meses en promedio), con los CAEs el plazo máximo de pago es menor a tres meses. Además, no depende tanto de la existencia de fondos puntuales de la Unión Europea (como los NextGen actuales), lo que garantiza un sistema con un horizonte a largo plazo y consistente en el tiempo. Esto simplifica el sistema y permite abordar mejoras en la eficiencia energética de inmediato, asegurando la competitividad.

Information failures and energy labelling in large purchase decisions

Ivan Petrov and Eleanor Denny***

Abstract

Not accounting for future energy costs is often cited as a barrier to the adoption of more efficient technologies. Numerous studies suggest that consumers are often uninformed of future energy use costs, particularly when making large purchase decisions such as homes or vehicles. Whether this can be corrected through information provision alone however remains unclear. This paper provides an overview of recent literature on labelling in energy efficiency adoption, focusing on energy efficiency information provision in two of the largest purchases households make – homes and vehicles. The literature suggests that while information failures are likely present, it can be difficult to fully correct these using simple information provision alone. Information failures also interact with other market failures, behavioural patterns and distributional issues. This underscores the need for policy measures in addition to labelling to encourage investments in efficiency.

Keywords: energy efficiency, market failures, information failures, framing, vehicle purchases, residential efficiency, labelling.

1. INTRODUCTION

The cleanest form of energy is the one that we do not use. Sometimes referred to as the *hidden fuel* since we can only observe it as the quantity of energy not used, improvements in *energy efficiency* have seen increased attention as a strategy to reduce greenhouse gas emissions. Perhaps they should be referred to as the *first fuel* (IEA, 2014).

It is useful to begin by providing a definition of energy efficiency. Fundamentally, the demand for energy can be viewed as a derived demand (Quigley, 1984). Consumers of energy typically do not demand primary (or even secondary)[1] energy itself but rather what that energy can do for them. In other words – consumers demand the *energy services* provided. For example, a consumer does not directly demand the kWh of electricity going into an electric light bulb, but rather the light coming from it. An improvement in energy efficiency can therefore be

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1 Primary energy typically refers to the resources captured directly from nature – for example crude oil, natural gas or solar energy. Secondary energy sources come from the transformation of primary energy sources – examples include electricity or petroleum products (OECD/IEA, 2004).

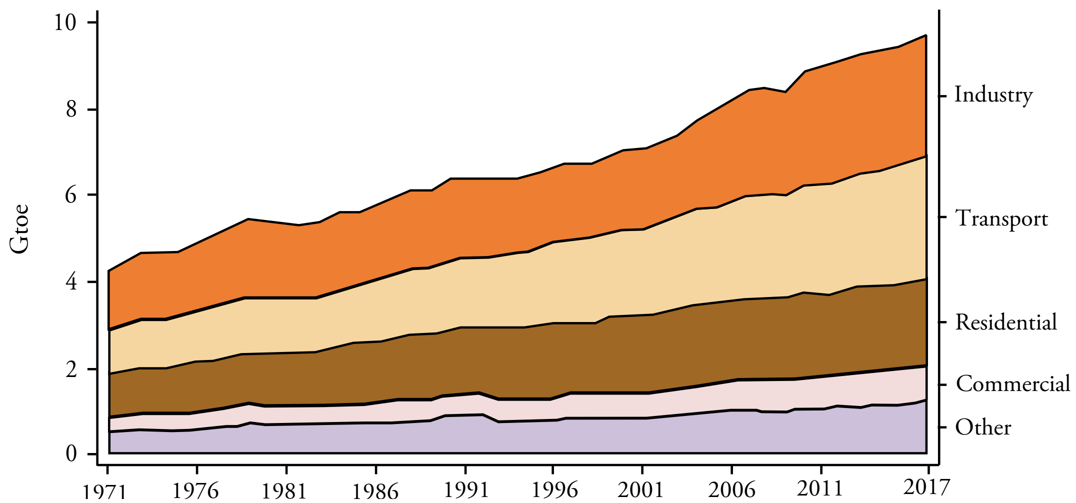
defined as obtaining the same (or better) levels of energy services, with less energy input. In our light bulb example, if we can obtain the same (or better) levels of light with less electrical input, this would be considered an improvement in efficiency.

It is also important to distinguish energy efficiency from energy conservation. As discussed in Linares and Labandeira (2010), energy conservation refers to an absolute reduction in energy demand. This can come from improvements in efficiency, or simply from a reduction in the energy services consumed. The distinction between energy efficiency and energy conservation is further exemplified by the fact that improvements in efficiency may not necessarily lead to proportional decreases in energy use. This is typically referred to as the rebound effect – a situation where more energy services are used as their per-unit cost decreases (Alberini *et al.,* 2016b; Gillingham *et al.,* 2013). Going back to our light bulb example, this would occur if a more energy efficient light bulb (being cheaper to operate) is left switched on for longer.

Notwithstanding limitations due to the rebound effect, the potential of energy efficiency in mitigating greenhouse gas emissions is non-trivial. IEA (2018) estimate that more than 40% of the emissions abatement required by 2040 to be in line with the Paris Agreement could be met by improvements in efficiency alone. Given that global energy demand has more than doubled in the last 50 years (figure 1),[2] and is projected to continue increasing (Smil, 2020)

Figure 1

Global final consumption of energy (gtoe) by sector



Note: "Other" includes agriculture, fishing, non-specified (other) and non-energy use.

Source: IEA (2020b).

2 According to the *World Energy Outlook* by the International Energy Agency (IEA), in 2017 global energy demand was projected to rise by a further 30% to 2040 – the equivalent of adding another China and India to today's global demand (IEA, 2017).

it seems likely that improvements in efficiency will play a key role in meeting future climate targets.

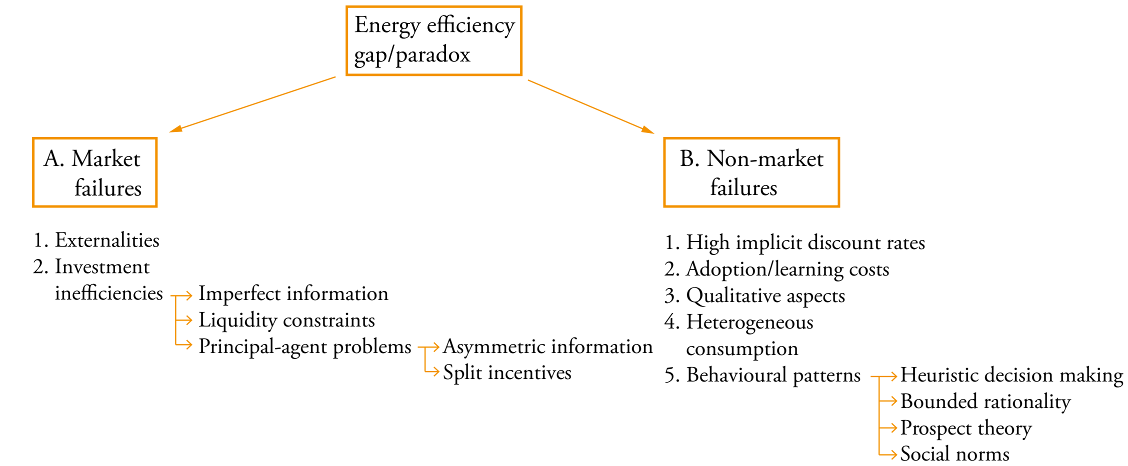
Two of the largest contributors to energy demand are the transport and residential sectors. Combined, they represent over 50% of total final global energy consumption. However, they also offer significant potential for improvements in efficiency from a household's perspective. In the residential sector, energy efficiency in buildings can be improved through the use of better building design, insulation materials, heating/cooling systems and appliances (IEA and UN, 2018). The transport sector offers efficiency gains which can be realised through modal shift (switching from private car to public transport), improvements in fuel economy, or a switch to alternative fuel technologies such as electric and hybrid-electric vehicles (SEAI, 2014).

Moreover, many improvements in efficiency can be cost effective, in addition to delivering a range of other benefits for the consumer (Ryan and Campbell, 2012). These can include health and wellbeing improvements and asset value increases in the case of properties. While many engineering studies highlight a range of energy efficient technologies that provide an attractive return on investment (Gerarden *et al.,* 2015; Wada *et al.,* 2012), the uptake of energy efficient technologies seems to remain below their economic potential. This is typically referred to as the "Energy Efficiency Gap" – a wedge between the cost-minimising level of energy efficiency and the level actually realised (Allcott and Greenstone, 2012; Jaffe and Stavins, 1994).

The economics literature has produced various explanations for the existence of this gap. These can be broadly categorised into two groups: market failures and other non-market failure barriers (figure 2). Market failures refer to situations where market conditions provide an inefficient outcome. These can result from flaws such as unpriced externalities, imperfect information or principal-agent problems. For example, if energy prices are too low due to unpriced environmental externalities, this may discourage investment in efficient technologies by lengthening their payback periods. If consumers are not aware of (or have imperfect information on) the energy cost savings which can be made by adopting more efficient appliances, this can also clearly prevent adoption. Asymmetric information between buyers and sellers of energy-using durable goods can also lead consumers to make purchases with suboptimal levels of efficiency, with sellers of inefficient goods having an incentive to conceal this information (Akerlof, 1970).

Typically, the presence of market failures gives clear justification for government intervention which can improve welfare (Baumol, 1972). Allcott and Greenstone (2012) categorise the market failures associated with energy efficiency in two broad sub-types: externalities and investment inefficiencies. The authors argue that government intervention in the form of subsidies or mandates for energy efficiency is only justified in cases where the market failure is not the result of unpriced environmental externalities, and cannot be fully addressed directly (for example by providing information to imperfectly informed consumers).[3]

Figure 2
Explanations for the energy efficiency gap



Sources: Allcott and Greenstone (2012), Gillingham *et al.* (2009).

Non-market failure explanations as per Jaffe and Stavins (1994) include high implicit discount rates, unpriced costs of adoption (such as learning costs), qualitative technological aspects, and heterogeneity in energy consumption. High implicit discount rates indicate that individuals may overly discount future benefits relative to the higher upfront purchase price of more efficient appliances. In a seminal work in the field, Hausman (1979) investigates how individuals trade-off of increased capital costs associated with more efficient air conditioners against lower future usage costs.[4] Individuals were found to behave as though they would require a return on investment of 20% in order to purchase a more efficient air-conditioner. Some authors have argued however that such high implied discount rates may not be irrational due to the uncertain nature of future benefits, and the irreversibility of efficiency investment decisions (Hassett and Metcalf, 1993). It is therefore unclear as to whether or not high implicit discount rates in of themselves are justification for government intervention.

Adoption or learning costs more generally occur when consumers need to consider efficiency differences between appliances, their own usage patterns, and how these may translate into

3 The authors argue that if energy use externalities are the only market failure, the social optimum will be obtained using Pigouvian taxes (or equivalent cap and trade programs) and not with other forms of intervention. If investment inefficiencies exist however, the first-best policy is to address the inefficiency directly – for example by providing information to imperfectly informed consumers. If these direct interventions are not fully effective and investment inefficiencies remain, only then is there rationale for policies that subsidise or mandate energy efficiency.

4 The idea of myopia with respect to future usage prices can be traced at least all the way back to Pigou, who commented on a "defective telescopic faculty" when it comes to future benefits (Hausman, 1979; Pigou, 1920, p. 25).

future monetary savings. There is a transaction cost associated with collecting this information and transforming it into an energy use forecast. Individuals may be unable or unwilling to carry out substantial research if the cost savings between energy-using goods are perceived as minimal, or of lesser importance than other product attributes (de Ayala *et al.,* 2020). Qualitative aspects, such as the appearance or other perceived functionality of an energy-using durable good may also prevent investments in efficiency if more efficient appliances are perceived to be of lower quality (Jaffe and Stavins, 1994). Heterogenous consumption might also imply that some individuals (particularly those with very low or irregular consumption patterns) will not benefit as much as median or mean consumers from investments in efficiency (Sekar *et al.,* 2019). Heavy users on the other hand may benefit much more.

The behavioural economics literature has yielded further non-market failure reasons for lower than expected investment levels in efficiency. Gillingham *et al.* (2009) include concepts such as bounded rationality, heuristic decision making and prospect theory as further barriers. Boundedly rational consumers may not be able to take all attributes of a purchase into account in complex trade-offs and time-limited decision contexts (Simon, 1979) and may experience information overload or a high cognitive load (Jacoby *et al.,* 1974). This may lead to heuristic decision making, whereby "rules of thumb" are used by consumers to simplify the decision process (Van Den Broek and Walker, 2019). Prospect theory suggests that individuals may overweight potential losses when compared to gains (Kahneman and Tversky, 1979), and may therefore place lower weight on potential future gains from efficiency investment when compared to the initial cost outlay. Social norms can also impact investments in efficiency through comparisons with other individuals. Social information may allow people to "fit in", avoid social disapproval, or seek social esteem (Farrow *et al.,* 2017). For example, Allcott (2011a) finds that providing social norm information in the form of relative electricity consumption (compared to neighbours) significantly reduces energy use among treated households.

These behavioural patterns can be influenced by altering the choice architecture consumers are faced with or by providing better or more targeted information. However, it is not as clear if these barriers in of themselves justify government intervention due to ethical concerns (Sunstein, 2015). Government interventions which "nudge" towards sustainable energy consumption may however be justified on the grounds that the energy system is "massively architectured" to begin with (Kasperbauer, 2017), and choices are being made in an environment where individuals are already strongly influenced by external factors.

A key theme which emerges from the framework in figure 2 is the importance of information in both market and non-market failure explanations to the energy efficiency gap. While imperfect information (or the absence of information) on energy cost savings associated with more efficient appliances is considered a market failure in its own right, it also interacts with other market and behavioural failures. For example, asymmetric information (which is one class of imperfect information) can interact with split-incentives in landlord-tenant relationships. Information asymmetries occur when one party in a contractual arrangement holds more information than the other party. Split-incentives can be defined as a goal conflict between the two parties. If tenants cannot observe the efficiency of the property, and are also responsible for energy bills (as is commonly the case in many rental arrangements), this may lead to a disincentive for landlords to invest in efficiency. Information failures are also clearly a factor in many of the behavioural explanations listed above, such as learning costs and bounded rationality which can stem from unclear or difficult to understand information.

Information failures can therefore ultimately lead to increased energy consumption. Ramos *et al.* (2015) discuss the implications of information interventions on efficiency investment and energy use more broadly, including the role of feedback and smart-metering on energy consumption. Solà *et al.* (2020) focus on the policy instruments which aim to alleviate the energy-efficiency gap, including non-information interventions such as standards and price instruments. Alberini (2018) highlights that there are many challenges when attempting to empirically estimate the effects of information and other policies on household energy use directly, which can include significant data limitations such as measurement error in estimating energy demand functions, response stickiness to excise taxes of fuels and energy inputs, salience, and rebound effects. The focus of this review paper is narrower in scope. We explore the role of information provision on the adoption of household efficiency measures, rather than on energy use. We focus specifically on two large purchase decisions – housing and vehicles – and discuss the role of efficiency labelling in both settings.

2. RESIDENTIAL ENERGY EFFICIENCY

2.1. Property purchases

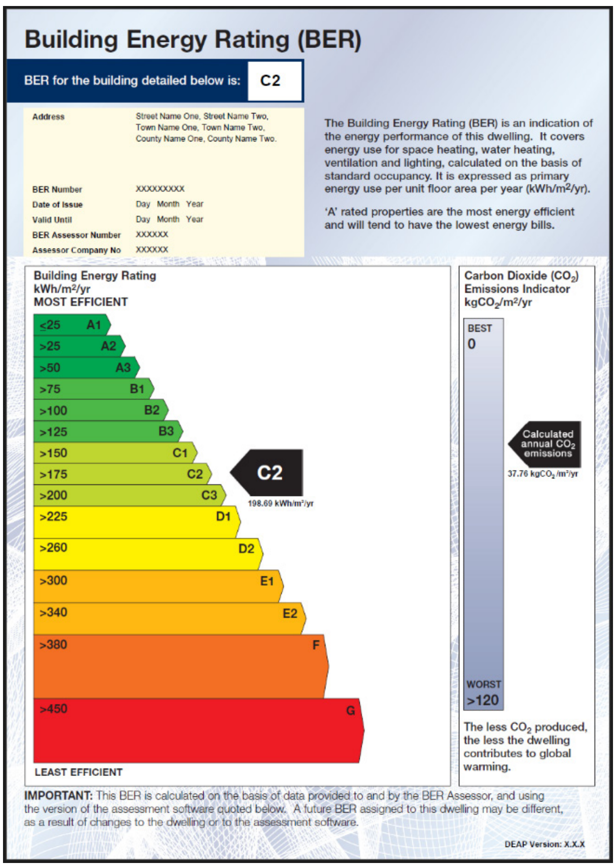
We begin by discussing the role of efficiency information in what is often the largest single purchase consumers make in their lifetime – their home. A central question in the literature is whether energy efficiency is capitalized in property prices. Numerous studies find a positive relationship between efficiency and sales values (Aydin *et al.,* 2020; Brounen and Kok, 2011; Cajias and Piazolo, 2013; de Ayala *et al.,* 2016; Fuerst *et al.,* 2015; Galvin, 2023). Since prospective buyers cannot directly observe the efficiency of a property (for example insulation levels or airtightness) in the absence of standardized labels, consumers may purchase properties with suboptimal levels of efficiency. This in part motivates the disclosure of energy performance certificates (EPC) in many countries in the European Union. Article 7 of the 2002 EU directive on the Energy Performance of Buildings (Directive 2002/91/EC, 2002) sets out the need for member states to adopt energy performance certificates which are to be displayed at the point of sale or lease of a property. In the Republic of Ireland, these are known as the Building Energy Rating (BER) and similar to other member states are based on a detailed engineering assessment of the dwelling (BPIE, 2014).

The assessment includes the measurement of wall, roof and floor dimensions, window and door sizes and orientation, as well as construction type and insulation, ventilation and airtightness features, the system for heat supply (including renewable sources), heat distribution and controls and the type of lighting (SEAI, 2013a). BERs are conducted by registered assessors and are valid for a period of 10 years. It is mandatory to provide a BER label (panel [b]) of figure 3) on the advertisements of properties offered for sale or rent across all media including in newspapers, magazines, brochures, leaflets, advertising notices, vehicle advertising, radio, television, internet (including apps and social media) and direct mail (SEAI, 2013b). The legislation mandating this came into effect on the 9th of January 2013 (*S.I. No. 243 of 2012*).

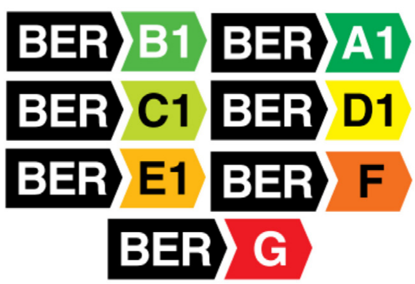
Figure 3

Example Building Energy Rating (BER) certificate and advertising labels

(a) BER certificate



(b) BER labels to be displayed with advertisement



Source: Sustainable Energy Authority of Ireland (www.seai.ie).

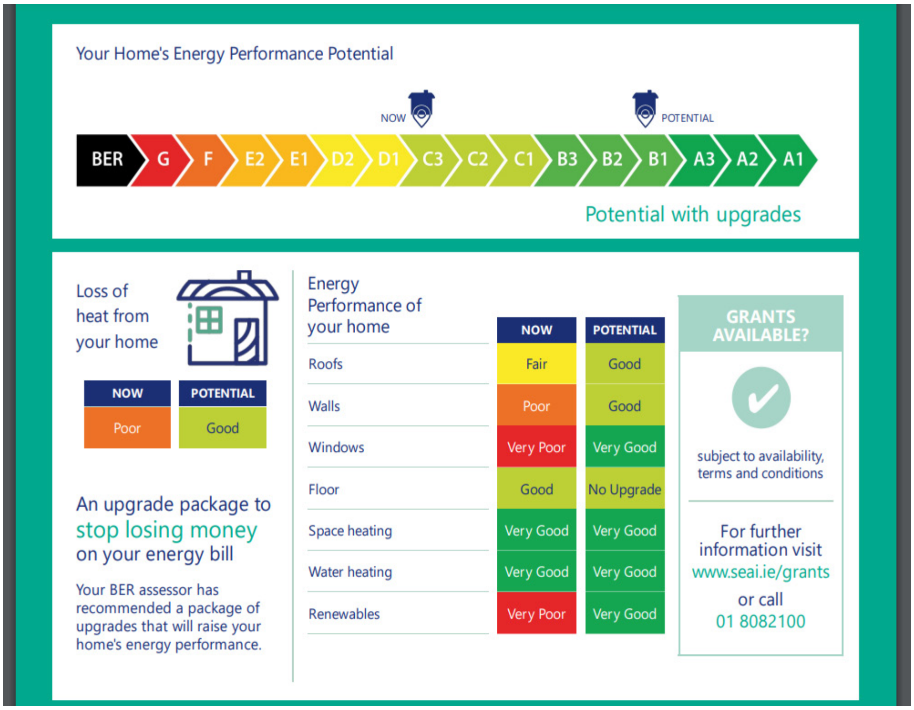
Multiple studies have found a positive relationship between a better BER rating and higher sales premiums. For example, using a Heckman selection model and advertisement data, Hyland *et al.* (2013) find that efficiency premiums are higher for properties advertised for sale (9% premium for an A-rating relative to a D-rating) than for rent (2% premium). Similarly, Stanley *et al.* (2016) also find a sales premium of 1% for each improvement in the alphanumeric BER grade, controlling for a wide range of property and location characteristics. A recent review of the European literature by Ou *et al.* (2025) presents similar findings across multiple European studies, with a one grade improvement in an energy performance certificate associated with a 1-3% price premium on average. In a review of international studies, Cespedes-Lopez *et al.* (2019) find that properties with a rating command a premium of 4.2% globally, relative to properties without a rating. However, the extent to which the BER itself (or other energy performance certificate) is responsible for correcting the information failure is unclear from these findings. The decision to advertise a rating (in cases where it is not mandatory) is likely correlated with other unobserved property or seller characteristics. Where advertised, better ratings may also be correlated with other unobservables, such as overall property quality. It is also difficult to gauge whether in the absence of such certificates, the efficiency of the property would not have been capitalized in sales prices to begin with. To address these identification issues, Frondel *et al.* (2020) examine the impact of transitioning from voluntary to mandatory EPC disclosure in the German market – and find that sellers of less-efficient properties revise their offer prices downwards post mandate. This suggests that energy performance certificates are communicating the inefficiency of low-rated properties to consumers, and are therefore increasing transparency in the market.

In a related vein, an area of further concern is how well energy performance certificates are understood by prospective purchasers. While the alpha-numeric colour coded scale used to display efficiency is designed to make it easy to assess relative differences between properties, how the rating can be translated into an energy cost forecast may not be obvious to buyers. Using a nationwide experiment, Carroll *et al.* (2024) find that providing monetary energy cost information (in the form of an energy cost forecast) in addition to the efficiency label in online advertising increases transaction sales premiums for efficiency and reduces the time it takes sell a property. This suggests consumers may be missing a key piece of information from the BER label – the monetary cost implications associated with the efficiency level of the property.

Further potential issues identified with the rating system come from the nature of threshold values used to determine which alpha-numeric grade category a rating falls into. Collins and Curtis (2018) find significant excess bunching (or grouping) of properties on the favourable side of threshold values post-retrofit, which may suggest strategic improvements in efficiency to reach a better grade. Since only the letter grade is advertised, this may mean that consumers should assume that within grades, the efficiency of the property is likely in the lower range of a band's kWh/m^2/yr values. This may also be applicable in other settings where a continuous efficiency measure is discretized to produce alpha-numeric grades. Other issues identified with energy performance certificates such as the BER is a potential lack of realism with respect to real-world consumption data (Coyne and Denny, 2021), which may be driven by prebound effects (households in less-efficient housing underheating their property) or rebound effects (households in more-efficient properties heating their homes to a higher temperature, for longer durations, or heating more rooms of the property). Meles *et al.* (2023) find that even controlling for set-point (thermostat) temperature and outside ambient temperature, implied energy savings by the BER are not fully realized in consumption data. While a standardized level of usage is necessary to provide an objective measure of efficiency, it has been found in other settings also that engineering estimates of efficiency improvements on consumption can be greater than realized benefits (Fowlie *et al.*, 2018; Levinson, 2016). This highlights the need to incorporate historical consumption data to improve a rating's accuracy.

Notwithstanding the limitations of energy performance certificates in communicating the efficiency of a property to potential buyers, there are also other benefits from this type of information which are in addition to correcting information asymmetries between buyers and sellers. The provision of publicly accessible efficiency data is important in guiding overall

Figure 4
Extract from BER advisory report



Source: Sustainable Energy Authority of Ireland (www.seai.ie).

policy and identifying disadvantaged areas (Ali *et al.,* 2021). Energy performance certificates also provide useful information to current property owners even if the property does not transact, which can guide retrofit decisions. In the Republic of Ireland, the BER assessment also includes an advisory report (figure 4) which identifies opportunities for improvements in efficiency through different measures, with estimated associated costs and information on grants and supports available. BER assessments must also be conducted prior to receiving government supports for retrofit in order to gauge the extent of improvement. Furthermore, energy performance certificates may also stimulate future investments in efficiency beyond what is already in place at the time of sale, since many purchasers of second-hand properties carry out renovation work post-purchase.

From a researcher perspective, the availability of efficiency data on properties also enables novel insights which can aid in further improving energy conservation, and the methodologies for measuring efficiency (BPIE, 2014). The communication and normalization of energy efficiency in the public discourse is also likely to draw further attention to efficiency improvements. The value of information provided by energy performance certificates is therefore likely to extend beyond the realm of simply correcting information asymmetries between buyers and sellers, and may have additional public good benefits.

2.2. Rental properties

Information asymmetries can also interact with other market failures. In the case of rental properties, the misalignment of incentives for efficiency investments or energy conservation is facilitated by information asymmetries. This misalignment of incentives is typically referred to as the *split-incentives or landlord-tenant* problem. It can be characterized as a principal-agent problem, since the party responsible for investment in efficiency or energy conservation (the principal) may not necessarily act in the interests of the other party (the agent) in the contractual arrangement (Eisenhardt, 1989). This can lead to an under-investment in energy efficiency by landlords or an over-consumption of energy by tenants, depending on which party is responsible for energy-related utility bills. Some authors have suggested that this may be a significant barrier to improving energy efficiency in residential properties. Murtishaw and Sathaye (2006) estimate that as much as 35% of primary residential energy use in the US may be affected by landlord-tenant problems. In the Netherlands, IEA (2007) find that up to 41% of the energy consumption for space heating in the residential sector might be affected by principal-agent issues, owing to a high proportion of rental properties. Homeownership rates have seen a decline in recent years across many Western countries (Billings and Soliman, 2023; Goodman and Mayer, 2018), and if this trend is to continue this will become an increasingly important barrier to efficiency investment and energy conservation.

Figure 5
Split-incentives problem

	Occupant owns dwelling	Occupant rents dwelling
Occupant pays for energy use	(1) No split-incentives	(2) Efficiency problem: asymmetric information leading to less insulation and efficient appliances
Occupant does not pay for energy use	(3) Both	(4) Usage problem: Over-use of energy due to moral hazard problem

Source: Adapted from Gillingham *et al.* (2012).

The above illustrates the split-incentives problem in the owner-occupant relationship. In case (1) there are no split incentives problems since the owner is also the occupier of the property and can decide to invest in efficiency or not, and therefore obtain the benefits in reduced energy bills (or not). Similarly, energy conservation efforts are also captured directly by the occupant, since the utility bill is also the responsibility of the occupant.

In case (2), the occupant rents their dwelling from another individual (or organization) however is responsible for energy utility bills. This is perhaps the most common type of rental arrangement, and may lead to under-investment in efficiency since landlords cannot benefit directly from efficiency investments. Such benefits accrue to the tenant. Where information problems can arise within this relationship is when tenants are not perfectly informed or cannot observe the efficiency of the dwelling prior to entering into a rental contract. Uninformed tenants may end-up paying high energy costs without the ability to change the efficiency of the property through, for example, insulation or heating system upgrade. Even in cases where tenants may have the option to purchase more efficient equipment, they may be unwilling to make these types of investments depending on planned tenancy duration, and also do not capture the benefits of increased property asset values associated with efficiency. There is therefore an incentive for landlords of inefficient properties to not-report efficiency information to prospective tenants. In the spirit of Akerlof's (1970) *market for lemons,* this may lead to a decline in the efficiency of the stock of rental properties available as a whole. Many studies find an efficiency difference between rental and non-rental properties which may be attributable to this form of asymmetric information, typically finding that rental properties are less likely to have efficiency measures such as insulation or efficient appliances (Gillingham *et al.,* 2012; Scott, 1997). Specifically for Ireland, findings from Petrov and Ryan (2021) suggest that rental properties have a lower BER rating overall when compared to similar non-rental counterparts.

In case (3) of figure 4 there is both the incentive to underinvest in efficiency and to over-consume energy. While rare, these cases can occur in collective heating arrangements where owners pay a fixed fee for utilities. Finally in Case (4), the split incentives problem is reversed. Here, the energy bills are the responsibility of the landlord, and tenants may pay a fixed fee for utility bills, or the utility bills are included as part of the overall fixed rent amount. In this instance there is an incentive for tenants to over-consumer energy if they face zero marginal cost with energy use. The information problem here is reversed – landlords may not be able to observe or control the usage patterns of the tenant, leading to a moral hazard problem. It has been documented that tenants with this type of heating arrangements tend to over-consume energy (Gillingham *et al.,* 2012; Levinson and Niemann, 2004).

The benefit of efficiency information in rental arrangements (particularly where tenants are responsible for energy bills) may also be higher than in purchase settings, due to potentially higher levels of exposure of the efficiency label. If tenure duration is shorter in rental accommodation than in owner-occupied properties, the label may be advertised and observed more often. Prospective tenants are also unlikely to conduct a detailed engineering assessment of the property as is commonly the case when a property is bought. Coupled with the incentives problems outlined above, there may be more value in efficiency information provision in the rental sector. Using stated preference methods Carroll *et al.* (2016a) find that tenants have significant willingness-to-pay for rental properties with a better BER which is in excess of the implied energy cost savings. Respondents also exhibit significant disutility with properties in the least efficient categories, and will pay significantly more for improvements at the lower end of the efficiency scale. When the energy savings associated with a more efficient rental property are presented as monetary amounts in Carroll *et al.* (2022) willingness to pay for efficiency improvements increases. As in the property sales domain, this again suggests that presenting energy cost savings as a monetary amount (rather than simply as an alphanumeric label) may further increase the demand for efficiency.

3. CAR PURCHASE CHOICES

A vehicle is typically the second-largest single purchase a household will make. Such purchases can also be made multiple times, offering substantial opportunities to communicate and invest in efficiency. Energy efficiency in the passenger car domain is typically referred to as fuel economy (or gas-mileage). As before, the demand for energy can be thought of as a derived demand, since consumers typically demand the energy service (car transportation) rather than the energy vector itself (gasoline or diesel). Improvements in fuel economy in turn are directly related to reductions in greenhouse gas emissions, which is one of the many externalities associated with passenger car use.[5]

5 Tail-pipe CO_2 emissions are only one of many external costs imposed on society when operating a passenger car. As per Parry *et al.* (2007) other associated costs include localised air pollution, congestion, noise, oil dependence and accident risk.

Many studies have attempted to estimate the degree to which consumers undervalue future fuel costs when making a new car purchase. Typically, a valuation ratio or parameter is estimated, which reflects the degree to which discounted future energy costs are internalized in purchase decisions. While earlier literature in the area suggests that the evidence for or against undervaluation of fuel economy is mixed (for reviews refer to Greene, 2010; Helfand and Wolverton, 2011), many recent studies have found that the valuation parameter is less that one (Allcott and Wozny, 2014; Gillingham *et al.,* 2021; Grigolon *et al.,* 2018; Leard *et al.,* 2023, 2020). This suggests that consumers may not be fully taking into account future car running costs when making a purchase decision.

The degree to which consumers undervalue fuel economy is unclear, with significant differences in findings across studies. Exploiting fuel price variation, Allcott and Wozny (2014) estimate a valuation ratio of 0.76 in the US, indicating that every $1 in discounted future fuel costs is valued at $0.76 in car transaction prices today. In contrast, Busse *et al.* (2013) do not find evidence of myopia with respect to future fuel costs, finding implicit discount rates for efficiency of similar magnitude to interest rates paid by buyers who borrow to finance their car purchase. In the EU Grigolon *et al.* (2018) find a more modest undervaluation (€0.91 for every €1), and suggest that fuel taxes may be more effective at reducing fuel usage than product taxes/subsidies, since they preferentially target high mileage users. Other more recent studies in the US such as Leard *et al.* (2023, 2020) find that the undervaluation of fuel economy may be higher (at $0.54 for every $1 in future fuel costs) due to higher valuation of other car attributes, such as acceleration and performance. Using a natural experiment (a re-statement of fuel economy labels), Gillingham *et al.* (2021) find that consumers value $1 in discounted future costs at only $0.16 - $0.39 cents in purchase prices, which suggests a larger degree of undervaluation. The fact that consumers changed their valuation of fuel economy (without any underlying change in the vehicles themselves) also illustrates that consumers do place a value on the fuel economy label itself.

While most of the above studies suggest that consumers do not fully take into account future energy cost associated with car use, the extent to which an additional information intervention can correct these errors and ultimately alter purchase choices is unclear. In stated preference settings it is found that consumers' preferences for fuel economy can be altered by providing additional information, particularly when this information is framed in monetary terms (Brazil *et al.,* 2019). The presentation of CO_2 information and its framing is also found to be effective in altering stated preferences towards less polluting vehicles (Daziano *et al.,* 2017; Wang *et al.,* 2021). What information is presented, its framing, and relative comparisons are also shown to be of importance in Codagnone *et al.* (2013). The presentation of running costs in particular appears to be an effective nudge. A more recent study conducted for the Directorate-General for Climate Action (European Commission *et al.,* 2021) suggests that presenting labels via online channels could have a large impact on the sales of new vehicles, and recommends the establishment of online comparison platforms. In a large 8,000 participant study conducted as part of the report it was found that the provision of running cost, air pollution and electric range bring about the most significant benefits.

However, it has been found to be more difficult for labelling interventions to substantially influence purchase choices outside of hypothetical settings. In that regard, there is a paucity of experimental research which aims to actively provide energy cost information to consumers at the point of sale. Allcott and Knittel (2019) use a randomized experiment to provide energy use cost information to vehicle shoppers and do not find that this altered purchase choices towards more fuel-efficient vehicles, highlighting the difficulty in altering preferences in real-world applications. By contrast, when it comes to vehicle tax information, using a randomized information experiment in Switzerland Cerruti *et al.* (2023) find that providing information on the existence of fiscal incentives for fuel economy increases awareness and leads consumers to purchase more efficient vehicles.

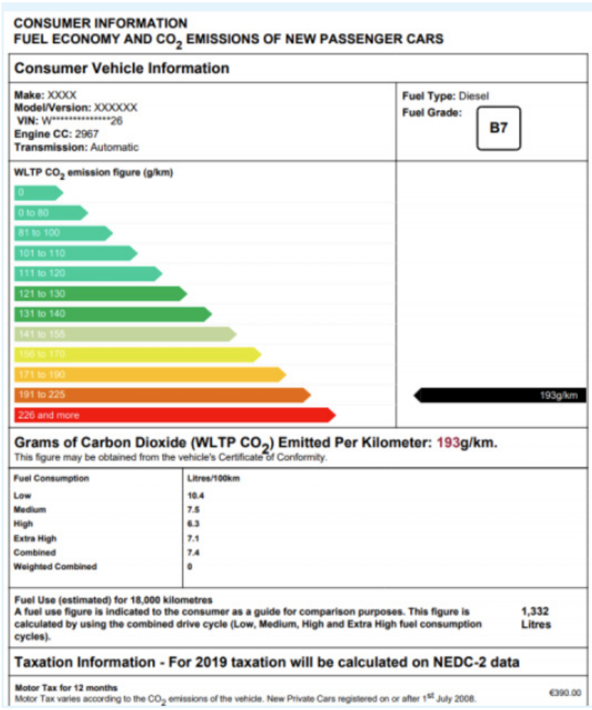
As with property efficiency, many countries also mandate efficiency labels to be displayed on new vehicles offered for sale. Directive 1999/94/EC requires EU member states to ensure that consumers are informed about the fuel economy and CO_2 emissions of new passenger cars through labelling, however these are not uniform across countries (Haq and Weiss, 2016). These labels are typically based on fuel economy and emissions ratings from testing procedures to ensure vehicle compliance with environmental and safety regulations. Examples of these for Ireland, Switzerland and the US are presented in figure 6.

In Switzerland, Alberini *et al.* (2016a) find a significant price premium to more efficient cars, suggesting that consumers place a value on fuel economy. Again however, as in the property labelling domain, the issue is whether this is simply the effect of the underlying efficiency of the vehicle or as a result of labelling policy correcting information asymmetries. To address this, the authors use a regression discontinuity design and find that an A rated vehicle receives an excess price premium of 6-11% relative to almost identical vehicles which are just below the A threshold value. This illustrates that consumers place a value on the A certification itself, which is beyond the value of the underlying efficiency. Interestingly, this premium is absent for B or C rated vehicles, suggesting that there may be an asymmetric effect of labelling which favours the most efficient (A) categories. The authors suggest that one explanation for this could stem from consumer heterogeneity, with those that place the highest value on efficiency seeking out vehicles with the best rated fuel economy. This correlates with findings by Hahnel *et al.* (2015) where "green" labelled vehicles were preferred by respondents with high ecological motivation, even when presented with product information that contradicts the label's image.

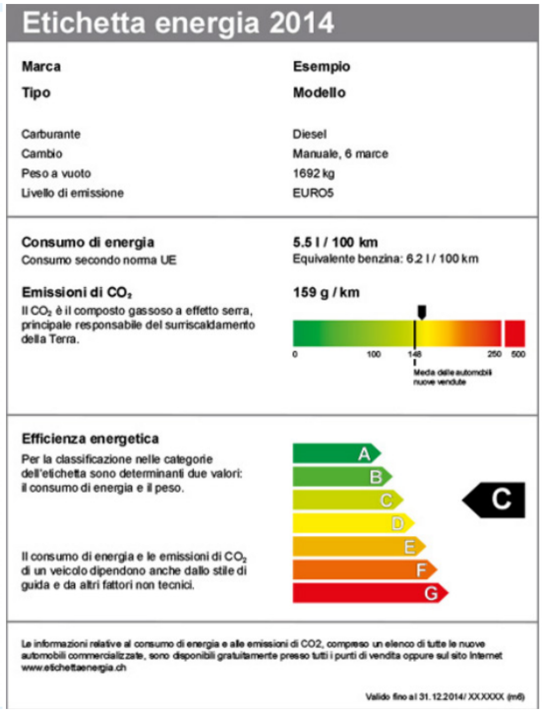
Figure 6

Car fuel economy and CO_2 labels

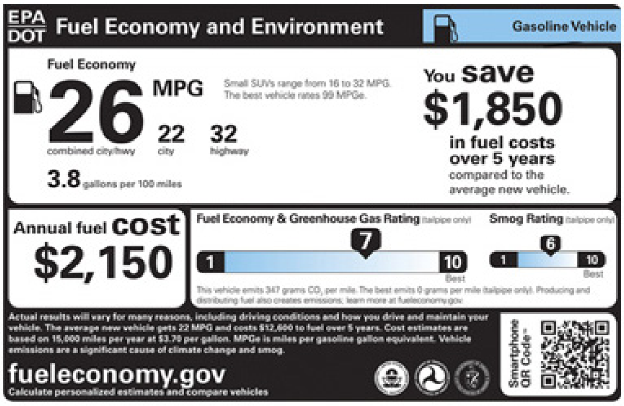
(a) Ireland



(b) Switzerland



(c) US EPA

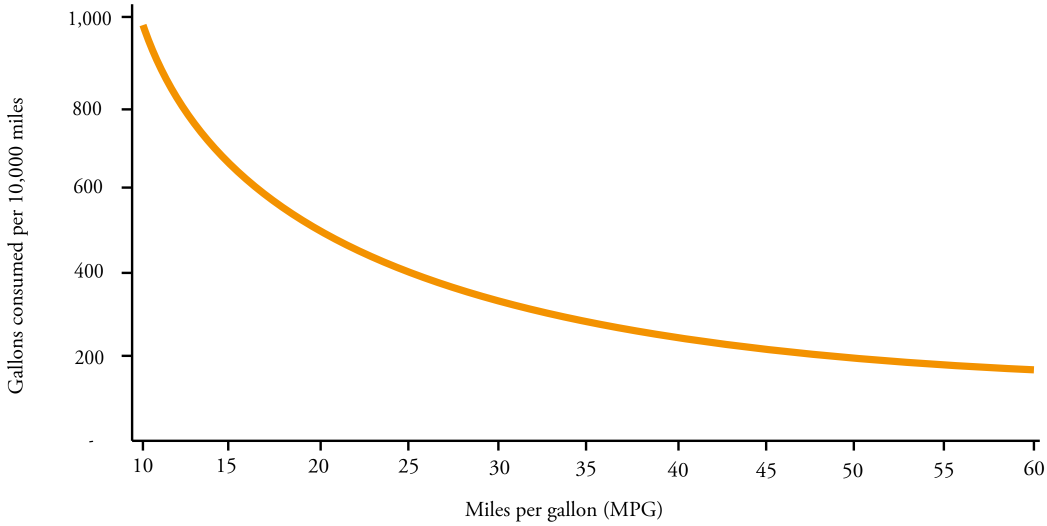


Notes: (a) Society of the Irish Motor Industry (SIMI, 2025), (b) Switzerland (Cerruti *et al.*, 2023) and (c) US Environmental Protection Agency (US EPA, 2024).

As with property efficiency labels, a further concern may be the extent to which consumers understand and internalize the fuel economy information contained in labels. Brazil and Caulfield (2017) use eye-tracking technology to test which aspects of the car label in Ireland attract the most attention. Most respondents focus their attention on the top of the colour coded rating (where the best performing vehicles are located), followed by the estimated annual fuel consumption of the car, its annual tax, and purchase tax rate. This may relate to the findings by Alberini *et al.* (2016a), whereby the "A" rating receives disproportionately more attention than the remaining grades. Other centres of attention found in Brazil and Caulfield (2017) correspond to the fuel consumption information at the bottom of the image and the details of the make and model of the car. This suggests that participants do pay attention to the fuel economy information in the label, however how well this fuel consumption information (in litres per 100km) is understood by consumers remains an area of concern. Turrentine and Kurani (2007) find in interviews that households do not analyse their fuel costs in a systematic way when making car or gasoline purchases. Using survey data in the US, Allcott (2011) also finds that American consumers devote little attention to fuel costs when purchasing vehicles.

In the US (panel [c] of figure 6), the top left quadrant of the car information label displays fuel economy in miles-per-gallon (MPG). Some studies find evidence of a MPG illusion (Larrick and Soll, 2008) whereby differences in fuel economy among higher MPG values are perceived

Figure 7
Miles per gallon (MPG) illusion



Note: "Figure illustrates the number of gallons of gasoline consumed per 10,000 miles driven at different MPG values (Larrick and Soll, 2008).

Source: Larrick and Soll (2008).

to have similar impacts on total fuel consumption as differences at lower MPG values. For example, the difference in total fuel consumption for a fixed driven distance between two cars rated at 11 MPG and 13 MPG is approximately the same as between two cars rated at 29 MPG and 49 MPG (Allcott, 2011b). This is illustrated in figure 7.

How the fuel economy/efficiency information is presented and understood by consumers is therefore of importance in facilitating comparisons between vehicles. Allcott (2011) argues that it is unclear whether the MPG illusion would influence consumers to purchase either vehicles with very low or very high fuel economy, since it should lead consumers to underestimate fuel economy differences in low MPG vehicles, and to overestimate the savings of the highest MPG vehicles. In Europe this should not be an issue since most labels display fuel economy as l/100km and therefore consumption scales linearly. However, the extent to which the l/100km metric is understood by European consumers and factored into future energy use forecasts is still unclear and warrants further future research.

4. DISCUSSION AND CONCLUSIONS

This paper discusses some of the issues around efficiency information provision in household purchase decisions. We focus our review on two of the largest purchases households typically make – housing and vehicles. Imperfect information is a likely barrier to efficiency investment in these settings, and therefore as per Allcott and Greenstone (2012) a first-best policy solution is to correct this by providing clear and easy to understand information. Information failures also interact with other market and non-market failure explanations to the energy efficiency gap, such as principal-agent problems and behavioural patterns. This suggests that there are potential multiple benefits of efficiency information provision beyond simply correcting information asymmetries between buyers and sellers.

In the property purchase domain, many studies find that more efficient properties are sold at a premium. Labelling has also been found to increase transparency in sales markets, particularly in the case of inefficient properties (Frondel *et al.,* 2020). There is therefore potential for labelling to improve welfare in property markets. This may be particularly true in the case of rental markets. Split-incentives problems and short tenure durations may mean that tenants are unable or unwilling to alter the efficiency of the property. If properties are let more often than they are sold, then the rating as an information measure may have greater exposure in rental markets – which could also mean greater value in information provision.

In the car purchase domain, many studies find that consumers undervalue efficiency (or fuel economy), and therefore labelling also has the potential to improve welfare. In stated preferences studies, it has been found that vehicle choice can be altered by additional monetary and emissions information provision. In revealed preference settings however, it appears to be more difficult to alter purchase choices simply through labelling at the point of sale. This may be due to preferences for other vehicle attributes (such as size or power), brand loyalty or due to timing in information provision. Consumers may conduct significant research on a vehicle of interest before going through with a purchase, therefore when the efficiency information is presented is likely important. Trust in emissions labelling in the car domain may be also of particular importance, given recent emissions scandals, and observed discrepancies between test results and on-road performance of vehicles (Tietge *et al.,* 2019).

Labelling may also have additional spillover benefits beyond correcting market failures at the individual level. Information from labelling may raise overall awareness of energy consumption and the role of efficiency in the public domain. This may lead to improvements in overall energy literacy. There may also be spillover effects into other domains, such as environmental awareness. In addition, labelling also provides important data which can be used in evaluating and guiding policy.

However, it is also important to understand the limits of information provision via labelling in altering purchase choices and delivering investments in efficiency. It is unclear whether efficiency information is fully understood by consumers, due to the complexity in calculating energy savings which include the need to understand and forecast energy prices and consumption. Monetary information provision (presenting efficiency information as €/$ bill savings) has been found to increase the demand for efficiency in multiple settings and research designs – highlighting a potential refinement to efficiency information provision. Monetary information however does not take into account the rebound effect or significant heterogeneity in usage patterns. Furthermore, efficiency measures may be subject to potential biases and errors in engineering estimates, and therefore need to be calibrated against real world consumption data where available.

It is also important to place the role of information provision within the context of other barriers, such as high up-front costs of more efficient purchases, principal-agent issues and uncertainty regarding future energy prices. For example, low-income households may be well aware of the benefits associated with efficiency improvements, however may not be able to realize these benefits due to prohibitively high upfront costs for investments in efficiency. Low-income households are also more likely to be in rental accommodation and therefore exposed to principal-agent issues. In these cases, it is clear that labelling alone may not encourage the adoption of more efficient appliances and therefore additional targeted supports or mandates for efficiency may be needed.

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Disposición a pagar por las etiquetas de eficiencia energética en electrodomésticos en España: el caso de las lavadoras*

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Resumen

Los electrodomésticos representan una proporción considerable del consumo eléctrico residencial, lo que los convierte en un objetivo clave para los esfuerzos de ahorro energético. Las etiquetas de eficiencia energética son un instrumento fundamental para informar a los consumidores sobre la eficiencia de los aparatos y fomentar la compra de aquellos más eficientes. Este artículo aplica el método de precios hedónicos para estimar la prima de precio asociada a la eficiencia energética en el mercado de lavadoras en España. Los resultados indican que los consumidores están dispuestos a pagar una prima del 11 % por lavadoras de alta eficiencia energética, en comparación con otras de las mismas características, pero menos eficientes. Esto equivale aproximadamente a 67 euros sobre el precio medio de mercado de las lavadoras en España. Además, se observa un aumento de más del 5 % en esta prima entre 2012 y 2019. El análisis también muestra que otros atributos, como la marca, el lugar de venta, la eficiencia del centrifugado y el hecho de que sean lavadoras integrables, juegan un papel clave en la decisión de compra.

Palabras clave: modelo de precios hedónicos, etiqueta de eficiencia energética, electrodomésticos (lavadoras).

1. INTRODUCCIÓN

Con el aumento del nivel de vida, el número de electrodomésticos en los hogares está creciendo rápidamente, al igual que el consumo eléctrico doméstico (Wang *et al.,* 2021). En el contexto del cambio climático y los planes de la Unión Europea (UE) para transitar hacia una economía limpia y neutra en carbono para 2050 (COM, 2019), el sector doméstico es uno de los que debe abordarse con urgencia. El consumo energético de los hogares representa alrededor del 26 % del consumo final de energía en Europa (Eurostat, 2021) y el 17 % en

* Los autores agradecen la financiación recibida del Proyecto "Evaluación de políticas para la transición energética" con referencia: PID2022-136376OB-I00 financiado por MCIN/ AEI /10.13039/501100011033/ y por "FEDER Una manera de hacer Europa".

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España (IDAE, 2021a). Además, supuso aproximadamente el 17 % de las emisiones globales de CO_2 relacionadas con la energía en 2019 (ONU, 2020).

Más concretamente, los electrodomésticos son una de las principales fuentes de consumo energético en los hogares (IDAE, 2021b). En la UE, los electrodomésticos y la iluminación representan el 57 % del consumo total de electricidad residencial (Eurostat, 2019). En España, esta cifra alcanza aproximadamente el 62 %. Por lo tanto, son productos clave para los esfuerzos de ahorro energético.

La eficiencia energética (EE) ofrece una oportunidad para reducir sustancialmente el consumo energético de los hogares (Linares y Labandeira, 2010). Diversos estudios han analizado el potencial de ahorro energético, la reducción de emisiones de CO_2 y la rentabilidad de las inversiones en eficiencia energética en el ámbito doméstico (Cattaneo, 2019; Ramos *et al.,* 2016, 2015; Stieß y Dunkelberg, 2013).

Sin embargo, a pesar de los beneficios económicos y ambientales potenciales de la EE, su nivel de adopción suele ser bajo, como muestra la literatura sobre la brecha de eficiencia energética (EE gap) (Linares y Labandeira, 2010). Esta brecha puede explicarse por diversos fallos y factores, como fallos de mercado (incluidos los informativos), fallos de comportamiento y/u otros factores (por ejemplo, normas sociales, procrastinación o experiencia personal) (Solà *et al.,* 2020).

Los fallos de información son de los más comunes y se refieren a situaciones en las que los consumidores carecen de información necesaria o la interpretan incorrectamente, lo que impide tomar decisiones óptimas. En el caso de los electrodomésticos, el hecho de que los consumidores no perciban directamente la cantidad de electricidad consumida por el aparato contribuye a esta brecha. Así, la EE en el mercado de electrodomésticos presenta varios problemas de información que son: (i) frecuentemente imperfecta y asimétrica; (ii) casi siempre difícil de obtener; y (iii) generalmente limitada a los costes de operación para los consumidores (Ramos *et al.,* 2015; Solà *et al.,* 2020).

Existen varios instrumentos de política para abordar estos fallos: certificados y etiquetas energéticas, herramientas de retroalimentación informativa y auditorías energéticas (Cattaneo, 2019; Labandeira *et al.,* 2020; Ramos *et al.,* 2016). El instrumento más común para reducir los fallos informativos son las etiquetas de (EE). Estas etiquetas proporcionan información sobre el consumo energético de los productos relacionados con la energía y sus niveles de eficiencia, junto con otros datos técnicos (por ejemplo, consumo de agua, capacidad, nivel de ruido). Su objetivo es proporcionar a los consumidores la información necesaria para realizar compras eficientes energéticamente.

Además, al establecer estándares mínimos obligatorios de EE, las regulaciones de etiquetado energético fomentan que los fabricantes adopten tecnologías más eficientes, modificando así la oferta de electrodomésticos en el mercado (Wang *et al.,* 2021). Sin embargo, sigue habiendo debates sobre la efectividad real de las etiquetas en la toma de decisiones de compra, debido a la persistencia de la brecha de EE (Galarraga *et al.,* 2011a; Wang *et al.,* 2021).

Este trabajo se centra en la etiqueta de EE para lavadoras en España, un mercado especialmente relevante debido al alto consumo eléctrico de este electrodoméstico, que en 2019 fue el tercero más utilizado, representando aproximadamente el 11 % de la demanda total de energía de los electrodomésticos.

La etiqueta energética de las lavadoras proporciona información estandarizada sobre su consumo de electricidad, nivel de EE y otros consumos de recursos como agua, capacidad nominal, clase de eficiencia de centrifugado y nivel de ruido. La Directiva 95/12/CE (CE, 1995) sobre lavadoras ha sido modificada varias veces. Para una explicación más detallada de la normativa de la UE sobre EE de los electrodomésticos, véase Schleich *et al.* (2021).

Este artículo estima cuánto están dispuestos a pagar los consumidores en el mercado español de lavadoras por la etiqueta de EE. Para ello, se utilizan datos reales de compra de 2019 y se aplica el conocido método de precios hedónicos para calcular el diferencial de precio marginal debido a mejoras en la EE.

Un estudio anterior de Lucas y Galarraga (2015) también analiza la prima de precio de las lavadoras de alta eficiencia en España, entre otros electrodomésticos, usando datos de mercado. Sin embargo, dicho estudio empleó datos de 2012 y una especificación distinta del atributo de EE.

Nuestro estudio contribuye a la literatura de dos formas principales:

1. Estimando la prima de precio, lo que resulta útil para el diseño de programas de incentivos económicos orientados a la adquisición de electrodomésticos eficientes.

2. Comparando las primas de precio a lo largo del tiempo en un mismo país, lo que permite evaluar si la disposición a pagar (DAP) por la EE está experimentando un aumento.

Así, este trabajo contribuye a la literatura sobre primas de precio en electrodomésticos eficientes al ofrecer una actualización y comparación de la DAP, así como una reflexión sobre la efectividad de las políticas energéticas.

El trabajo se organiza de la siguiente manera: la sección dos revisa la literatura existente sobre primas de las etiquetas de EE en electrodomésticos, mientras que la sección tres detalla el método de precios hedónicos y los datos empleados para el análisis. La sección cuatro presenta los resultados, y la última sección está dedicada a las conclusiones.

2. REVISIÓN DE LA LITERATURA

Las investigaciones sobre la reacción de los consumidores ante las mejoras en EE en distintos mercados han crecido notablemente en los últimos años, impulsadas tanto por la implementación de etiquetas de EE como por la creciente preocupación por el medio ambiente y el cambio climático.

Existen numerosos estudios que analizan la eficacia de las etiquetas de EE en diferentes mercados de productos, como los electrodomésticos (Faure *et al.,* 2021; Galarraga *et al.,* 2011b, 2011a; Kesselring, 2023; Lucas y Galarraga, 2015; Schleich *et al.,* 2021; Zhang *et al.,* 2021), viviendas (Brounen y Kok, 2011; Copiello y Donati, 2021; de Ayala *et al.,* 2016; Evangelista *et al.,* 2022, 2020; Fuerst y Warren-Myers, 2018; Walls *et al.,* 2017), y automóviles (Alberini *et al.,* 2014; Arawomo y Osigwe, 2016; Galarraga *et al.,* 2020, 2014).

En el mercado de los electrodomésticos, existe una amplia evidencia que analiza el efecto de los niveles de EE en las decisiones de compra de diferentes aparatos (lavadoras, frigoríficos, lavavajillas, aires acondicionados, purificadores de aire y televisores) en diversos países (por ejemplo, España, Alemania, Suiza, China, Corea del Sur, Estados Unidos e India). Además, Kesselring (2023) ha estimado recientemente la DAP por la EE en siete países europeos y para dos tipos de electrodomésticos dentro del mercado de la UE.

La tabla 1 presenta una visión general de estos estudios empíricos, organizados por tipo de electrodoméstico, país y método empleado. Cabe destacar que las comparaciones entre las primas de precio por EE deben realizarse con cautela, debido a las diferencias en los niveles de EE y los métodos de valoración utilizados. Se observa, además, que existen diferencias significativas entre las primas de precio obtenidas mediante métodos de preferencias reveladas y preferencias declaradas, siendo generalmente más altas las estimaciones derivadas de preferencias declaradas.

En el caso específico de las lavadoras, la investigación sobre las primas por etiquetas de EE se ha realizado en varios países. Para España, Lucas y Galarraga (2015), utilizando el modelo de precios hedónicos, encontraron que en 2012 las lavadoras con la máxima etiqueta de eficiencia (A+++) presentaban una prima del 4,15 % respecto a aquellas con las mismas características, pero con menor eficiencia.

Además, otros estudios muestran resultados similares en otros países: en Suiza, la prima por una lavadora etiquetada A frente a una C fue de aproximadamente 30 % en 2004 (Sammer y Wüstenhagen, 2006), mientras que en China la prima media por cada mejora en el nivel de EE fue del 15,9 % en 2017 (Zha *et al.,* 2020). En el mercado europeo, Kesselring (2023) encontró que una mejora adicional en el nivel de EE implicaba una prima media del 0,64 % para el período 2010-2017.

Tabla 1
Estudios sobre primas de precio por etiquetas de eficiencia energética en electrodomésticos en diferentes países

Electrodoméstico	País	Prima de precio EE	Método	Año	Referencia
Lavadoras	España	4,15 % (19,79€)	Precios hedónicos	2012	(Lucas y Galarraga, 2015)
	China	15,9 % (424,76 RMB)	Elección discreta	2017	(Zha *et al.*, 2020)
	Suiza	30 % (455€)	Elección discreta	2004	(Sammer y Wüstenhagen, 2006)
	Europa	0,64 % (2,76€)	Precios hedónicos	2010-2017	(Kesselring, 2023)
Lavavajillas	España	4 % (19,28€)	Precios hedónicos	2012	(Lucas y Galarraga, 2015)
		15 % (80€)	Precios hedónicos	2009	(Galarraga *et al.*, 2011a)
Frigorífico	España	12,6 % (86,18€)	Precios hedónicos	2012	(Lucas y Galarraga, 2015)
		8,9 % (58,56€)	Precios hedónicos	2009	(Galarraga *et al.*, 2011b)
	Europa	0,8 % (3,13€)	Precios hedónicos	2010-2017	(Kesselring, 2023)
	China	28,1 % (1.162 RMB)	Precios hedónicos	2018	(Zhang y Tao, 2020)
		21,63 % (757 RMB)	Elección discreta	2006	(Shen y Saijo, 2009)
		23,09% (731,16 RMB)	Elección discreta	2017	(Zha *et al.*, 2020)
	EE. UU.	26,17 %-36,60 % ($249,82-$349,30)	Elección discreta	2009	(Ward *et al.*, 2011)
		6,66 %-10,66 % ($95-$152)	Demanda estructural	2008	(Houde, 2014)
		Over 28 % (Over $200)	Elección discreta	2009	(Li *et al.*, 2016)
	India	35 % ($100)	Elección discreta	2015	(Jain *et al.*, 2018a)
Aire acondicionado	China	12,4 % Around (703 RMB)	Precios hedónicos	2018	(Zhang *et al.*, 2021)
		8,12 % (276 RMB)	Elección discreta	2006	(Shen y Saijo, 2009)
		9,4 % (400 RMB)	Elección discreta	2013	(Zhou y Bukenya, 2016)
	India	24 % ($126,24)	Elección discreta	2015	(Jain *et al.*, 2018a)
		36 % ($137)	Elección discreta	2015	(Jain *et al.*, 2018b)

Tabla 1 *(continuación)*

Estudios sobre primas de precio por etiquetas de eficiencia energética en electrodomésticos en diferentes países

Electrodoméstico	País	Prima de precio EE	Método	Año	Referencia
Purificador de aire	Corea	9,1 % (40.000 KRW)	Elección discreta	2018	(Kim *et al.*, 2019)
Televisión	Corea	19,1 % (359,27€) --	a. Precios Hedónicos b. Elección Discreta	2012	(Park, 2017)
	Alemania	15,8 % (150€)	Elección discreta	2009	(Heinzle y Wüstenhagen, 2012)

Fuente: Elaboración propia.

En cuanto a los lavavajillas, la prima pagada en España por EE fue del 4 % en 2009 (Lucas y Galarraga, 2015) y del 15 % en 2012 (Galarraga *et al.*, 2011a).

En el caso de los frigoríficos, en España se identificaron primas del 12,6 % en 2009 (Lucas y Galarraga, 2015) y del 8,9 % en 2012 (Galarraga *et al.*, 2011b). En Europa, la prima media fue del 0,8 % para el período 2010-2017 (Kesselring, 2023). En otros lugares, las primas por frigoríficos oscilan entre el 22 % y el 28 % en China (Shen y Saijo, 2009; Zha *et al.*, 2020; Zhang y Tao, 2020) y entre el 7 % y el 37 % en Estados Unidos (Houde, 2014; Li *et al.*, 2016; Ward *et al.*, 2011), alcanzando cerca del 35 % en India (Jain *et al.*, 2021, 2018a).

Respecto a los aires acondicionados, en China se encontraron primas entre el 9 % y el 12 % (Shen y Saijo, 2009; Zhang *et al.*, 2018; Zhou y Bukenya, 2016) y en India una prima cercana a los 110 euros (Jain *et al.*, 2018a).

Para los purificadores de aire, Kim *et al.* (2019) estimaron una prima del 9 % en Corea en 2018. En cuanto a los televisores, Park (2017) identificó una prima del 19 % en Corea mediante el modelo hedónico, aunque no se halló prima cuando se usó un experimento de elección discreta. Finalmente, Heinzle y Wüstenhagen (2012) encontraron en Alemania una prima del 19 % para televisores con la máxima etiqueta energética en 2012.

Por tanto, se puede concluir que todos los estudios revisados encuentran, en general, una prima de precio positiva por la EE, aunque la magnitud de dicha prima varía según el país, la categoría de producto, el año de análisis y la forma de medir la EE. Estos resultados concuerdan con los de Kesselring (2023), quien también destaca una alta heterogeneidad entre países (países de Europa Central y del Este vs. Europa Occidental) y entre tipos de productos (lavadoras frente a frigoríficos) dentro del mercado común europeo.

Fuente: Elaboración propia.

Además, existen varios factores que pueden explicar un aumento en la prima pagada por EE a lo largo del tiempo, como las políticas públicas y otros esfuerzos para fomentar la EE. Más allá de las etiquetas, estas políticas incluyen contadores inteligentes, herramientas de retroalimentación informativa y auditorías energéticas (Cattaneo, 2019; Solà *et al.,* 2020). Otros factores se relacionan con cambios en el precio de la electricidad y factores del lado de la oferta, como estándares de EE y los progresos tecnológicos, que empujan a los fabricantes a adoptar tecnologías más eficientes debido a regulaciones obligatorias (Schleich *et al.,* 2021).

En todo caso, un aumento en la prima por EE puede interpretarse como positivo, ya que refleja una mayor valoración de la eficiencia por parte de los consumidores y contribuye al objetivo general de incrementar la adopción de tecnologías eficientes y reducir el consumo energético.

3. METODOLOGÍA

3.1. El método de precios hedónicos

La técnica de precios hedónicos se utiliza comúnmente para estimar cuánto del precio de un bien se explica por cada uno de los atributos que posee (Rosen, 1974). Este método permite analizar la relación entre el precio de un producto y sus distintos atributos, generando un conjunto de precios implícitos para cada una de esas características.

El método parte de la premisa de que los bienes se diferencian por el número y tipo de atributos que los caracterizan. Así, permite estimar la diferencia de precio entre dos productos con distinto nivel de EE, manteniendo constantes el resto de los atributos (Galarraga *et al.,* 2011a).

En la literatura, suele interpretarse como la prima de precio del atributo de EE o como la DAP de los consumidores por la EE al adquirir un electrodoméstico (Galarraga *et al.,* 2011a). Por tanto, la DAP (o coste real) por el atributo de EE refleja la preferencia o el grado de reconocimiento que otorgan los consumidores a dicha característica (Fernández *et al.,* 2019; He *et al.,* 2019; Zhang *et al.,* 2021).

En este trabajo, estimamos cuánto pagan realmente los consumidores en el mercado español de lavadoras por el atributo de EE. Una descripción completa de esta técnica puede encontrarse en Braden y Kolstad (1991) y Rosen (1974).

El método de precios hedónicos ha sido ampliamente aplicado para analizar los efectos de los atributos de los productos en sus precios, por ejemplo, en los mercados de viviendas (Copiello y Donati, 2021; Cornago y Dressler, 2020; de Ayala *et al.,* 2016; Delgado *et al.,* 2016; Kesselring, 2023), automóviles (Arawomo y Osigwe, 2016; Galarraga *et al.,* 2014) y electrodomésticos (ver sección dos), entre otros.

3.2. Datos

Los datos fueron recolectados de manera *online* en España por una empresa especializada en encuestas (CPS) entre junio de 2018 y mayo de 2019. Incluyen los precios de mercado a los que los consumidores podían adquirir una lavadora, así como información sobre los atributos del producto correspondiente a 322 modelos de lavadoras de 18 marcas distintas. Los datos provienen de catálogos *online* (18 %) y de las páginas web de diversas tiendas (82 %).

Dado que los 322 modelos se ofrecían a precios distintos según el distribuidor, el número total de observaciones de precios fue 739, distribuidas de la siguiente manera: catálogo (107 observaciones), El Corte Inglés (224), MediaMarkt (104), supermercados Carrefour (232) y supermercados Eroski (72). El precio medio de una lavadora fue de 612,60 euros.

Los datos también incluyen información sobre atributos técnicos, como:

- Nivel de EE.
- Marca.
- Consumo de agua en litros por año (consumo de agua).
- Capacidad nominal en kilogramos (capacidad).
- Clase de eficiencia de centrifugado (sdpA, sdpB o sdpC).
- Emisiones acústicas durante el lavado y centrifugado (en decibelios).

La EE en la base de datos se mide en una escala de A+++ (máxima eficiencia) a A+, siguiendo la Directiva de Etiquetado Energético de la UE (2010/30/UE) vigente en ese momento. Además, se incluye información adicional sobre reducciones de consumo energético entre un 10 % y 70 % respecto a la etiqueta A+++, con los siguientes niveles: 70 %, 60 %, 55 %, 50 %, 40 %, 30 %, 20 % y 10 %. Esta información, que amplía la etiqueta obligatoria, se añade en los puntos de venta (por ejemplo, A+++ -10 % de consumo energético).

Del total de la muestra, el 90,39 % corresponde a lavadoras A+++, 7,98 % a A++ y el 1,62 % a A+. Dada la alta proporción de lavadoras A+++, decidimos centrar el análisis en las lavadoras más eficientes, es decir, aquellas clasificadas como A+++ con una reducción adicional del consumo entre el 10 % y el 70 % (alto nivel de EE). Estas representan el 54,67 % de la muestra total. A diferencia del estudio de Lucas y Galarraga (2015), que solo consideraba la etiqueta A+++, nosotros valoramos estos niveles adicionales de eficiencia.

Entre los atributos técnicos específicos, al igual que en Lucas y Galarraga (2015), incluimos:

- Altura, anchura, profundidad, capacidad, color, eficiencia del centrifugado, y ruido del centrifugado.
- Además, añadimos: consumo de agua, tipo de carga (frontal o superior), si es integrable, marca y tienda.

Sobre las marcas, la mitad de las lavadoras pertenece a:

- SIEMENS (14 %), BALAY (13 %), AEG (8 %), SAMSUNG (8 %) y LG (7 %).
- La otra mitad incluye otras marcas como WHIRLPOOL, ZANUSSI, INDESIT, BEKO, MIELE, SMEG, CANDY, HAIER, HISENSE, TEKA, HOOVER y CORBERO.

Cada una de las 17 marcas se considera como variable ficticia (*dummy*), ya que reflejan factores como diseño, reputación y fiabilidad (Galarraga *et al.*, 2011a, 2011b; Lucas y Galarraga, 2015).

Las variables técnicas consideradas incluyen:

- Clase de eficiencia de centrifugado (A, B, C).
- Profundidad, altura, consumo de agua, color (blanca u otra), capacidad, tipo de carga (frontal o superior), ruido de centrifugado (dB) y si es integrable.

Algunos datos descriptivos:

- 16 % está en clase A (centrifugado), 67 % en B, 12 % en C.
- Promedios: anchura 581 mm, profundidad 578 mm, altura 849 mm, consumo de agua 10.145 litros/año, ruido centrifugado 74,55 dB.
- 92,56 % son de carga frontal, 80,65 % son blancas.
- Capacidad: entre 1 kg y 17 kg, destacando modelos de 7, 8, 8.5 y 9 kg (84 % del total).
- Solo 5,82 % son integrables.

3.3. Modelo de regresión

La variable dependiente es el logaritmo del precio (*lnprice*), que se regresa sobre distintas variables explicativas relacionadas con atributos.

La ecuación hedónica estimada es la siguiente:

$$\begin{aligned} Inprecio_i = \propto &+ \beta_1 EEAlto_i + \beta_2 Catalogo_i + \beta_3 El\ Corte\ Ingles_i \\ &+ \beta_4 Supermercado_i + \beta_5 Marca_i + \beta_6 sdpA_i + \beta_7 sdpB_i \\ &+ \beta_8 sdpC_i + \beta_9 Fondo_i + \beta_{10} Altura_i + \beta_{11} Consumo\ agua_i \\ &+ \beta_{12} Color_i + \beta_{13} Capacidad_i + \beta_{14} Tipo\ Carga_i \\ &+ \beta_{15} Ruido\ Centrf_i + \beta_{16} Integrable_i + \varepsilon_i, \end{aligned} \quad [1]$$

donde *Inprecio* es el logaritmo del precio de las lavadoras, $\propto$ es una constante y las variables explicativas son: (i) Comercios (catálogo, El Corte Inglés, supermercados); (ii) Marca (AEG, Balay, ..., Zanussi); (iii) Nivel EE (*nivel alto*); y (iv) Atributos técnicos (*sdpA, sdpB, sdpC, fondo, altura, consumo de agua, color, capacidad, tipo de carga, ruido centrifugado, integrable*).

Este modelo permite estimar cuánto paga realmente el consumidor por la lavadora con el mayor nivel de EE. Cabe destacar que los precios analizados reflejan tanto factores de demanda como de oferta, ya que corresponden a precios de equilibrio de mercado.

4. RESULTADOS Y DISCUSIÓN

El método de precios hedónicos nos permite estimar, *ceteris paribus* (es decir, cuando todos los demás atributos y características técnicas se mantienen constantes), la prima de precio de las lavadoras con el nivel más alto de EE.

Los resultados de la regresión del modelo hedónico de precios se muestran en la tabla 2. Además, un valor del R-cuadrado ajustado, cercano a 0,8, sugiere que el modelo se ajusta bien a los datos y explica una gran proporción de la variación en los precios.

Los resultados muestran un efecto positivo y significativo del alto nivel de EE sobre el precio. Es decir, las lavadoras con la etiqueta A+++ (junto con información adicional sobre ahorros de energía de entre 10 % y 70 %) tienen una prima de precio del 11 % en comparación con lavadoras de las mismas características pero con menor EE (A+++, A++, A+). Esto equivale a un incremento de 67 euros sobre el precio medio de 612,60 euros.

Nuestra estimación de la prima de precio coincide con la literatura previa, donde siempre se observa una prima positiva por EE, aunque con variaciones según tipo de electrodoméstico, país y año.

Lucas y Galarraga (2015), usando también el método hedónico, encontraron en 2012 una prima del 4,15 % (19,79 euros) para las lavadoras A+++. Aunque no es posible una comparación directa por los cambios en la etiqueta, parece que la prima por EE en lavadoras ha aumentado en España, más que duplicándose.

Tabla 2

Resultados del modelo de precios hedónicos

Variable	Coeficiente	Std. error	P>|z|
Nivel EE			
EE Alta	0,110***	0,023	0,000
Comercio			
Catálogo	0,183***	0,028	0,000
El Corte Inglés	0,154***	0,023	0,000
Supermercado	-0,061***	0,023	0,007
Marca			
Aeg	0,108***	0,033	0,001
Balay	-0,115	0,027	0,000
Beko	-0,271***	0,043	0,000
Candy	-0,105*	0,059	0,076
Corbero	-0,256***	0,078	0,001
Haier	-0,278***	0,055	0,000
Hisense	-	-	-
Hoover	-0,125*	0,070	0,074
Indesit	-0,185***	0,045	0,000
Lg	-0,252***	0,039	0,000
Miele	0,495***	0,048	0,000
Samsung	-0,001	0,047	0,983
Siemens	0,062**	0,027	0,021
Smeg	0,364***	0,051	0,000
Teka	-0,088	0,063	0,157
Whirpool	-0,103***	0,038	0,008
Zanussi	0,056	0,044	0,196
Atributos técnicos			
sdpA	0,327***	0,051	0,000
sdpB	0,100**	0,043	0,021
sdpC	0,015	0,045	0,738
Ancho	-0,000	0,000	0,197
Fondo	0,001***	0,000	0,000
Altura	0,001***	0,000	0,001
Consumo agua	0,000	0,000	0,101
Color	-0,155***	0,020	0,000
Capacidad	0,081***	0,012	0,000
Tipo de carga	0,010	0,054	0,855
Ruido centr.	-0,032***	0,004	0,000
Integrable	0,310***	0,041	0,000

Notas: ***, ** y * denotan significatividad del 1 %, 5 % y 10 %, respectivamente.

Este aumento puede deberse a los siguientes factores:

- Mejora en la información y concienciación sobre EE y cambio climático (Ramos *et al.*, 2015).
- Mayor reconocimiento y valoración de la etiqueta energética (de Ayala *et al.*, 2020; de Ayala y Solà, 2022).
- Avances tecnológicos y la percepción del precio de la electricidad, que fomentan la inversión en electrodomésticos eficientes (Schleich *et al.*, 2021).

Por países, la prima del 11 % es superior al promedio europeo (0,64 %), pero inferior a la de Suiza y China (Sammer y Wüstenhagen, 2006; Zha *et al.,* 2020).

Comparando con otros electrodomésticos, la prima en lavadoras es menor que en frigoríficos o televisores, lo cual podría explicarse por el hecho de que, aunque las lavadoras son importantes, no se usan tanto como los frigoríficos (funcionan 24/7) (IDAE, 2021b).

Los precios varían según el punto de venta:

- Lavadoras compradas por catálogo o en El Corte Inglés son 18 % y 15 % más caras, respectivamente.
- En supermercados, las lavadoras son un 6 % más baratas

Estos resultados concuerdan con los hallazgos de Lucas y Galarraga (2015), quienes encontraron un sobreprecio del 14 % en El Corte Inglés.

La marca también tiene un efecto importante sobre el precio:

- MIELE: prima del 49 %.
- SMEG (prima del 36 %), AEG (prima del 11 %), SIEMENS (prima del 6 %).
- Marcas de menor prestigio (BEKO, HAIER, CORBERO, INDESIT, HOOVER, WHIRLPOOL, CANDY) muestran un efecto negativo (hasta -27 %).

Estos resultados coinciden con Lucas y Galarraga (2015) y Sammer y Wüstenhagen (2006), quienes encontraron primas del 86 % para Miele y VZug.

Respecto a atributos técnicos:

- Centrifugado clase A (sdpA): prima del 33 %; clase B, 10 %.
- Ancho: no relevante.
- Profundidad y altura: efecto positivo pequeño.
- Consumo de agua: no significativo (similar a Lucas y Galarraga, 2015 y Zha *et al.,* 2020).
- Integrables: 31 % más caras.
- Color blanco: 15,5 % más baratas.
- Capacidad: más caras (+8,1 %).

- Ruido: menor precio cuanto mayor es el ruido (3,2 %).
- Tipo de carga: no significativo.

5. CONCLUSIONES E IMPLICACIONES DE POLÍTICA

Los electrodomésticos en España representaron aproximadamente el 62 % del consumo eléctrico residencial en 2019, lo que subraya la necesidad urgente de mejorar su EE. La EE ofrece una oportunidad clave para reducir sustancialmente el consumo energético en los hogares y alcanzar los objetivos de ahorro energético establecidos por las autoridades a nivel mundial. En este contexto, muchos países han introducido las etiquetas de EE como una política clave para lograr los objetivos energéticos y climáticos. Este instrumento de política tiene como objetivo incentivar a los consumidores a elegir productos más eficientes, proporcionando información clara, coherente y confiable.

Utilizando datos de mercado de 2019 en España, este estudio estima cuánto están dispuestos a pagar los consumidores por el atributo de EE, manteniendo constantes el resto de los atributos del electrodoméstico. Para ello, aplicamos el método de precios hedónicos, que nos permite calcular el diferencial marginal de precio asociado a las mejoras en EE.

Nuestros hallazgos aportan información relevante sobre la efectividad de las etiquetas de EE en lavadoras en los últimos años, en comparación con las primas de precio estimadas anteriormente en España para el mismo electrodoméstico. Además, contrastamos nuestros resultados con estudios similares que analizan otros electrodomésticos en diferentes países y periodos.

El método hedónico sugiere que la prima de precio pagada en el mercado por las lavadoras con el mayor nivel de EE es del 11 % del precio final, lo que equivale a 67 euros adicionales sobre el precio promedio estimado de las lavadoras en el mercado español. Aunque los cambios en el diseño de las etiquetas de EE y las diferencias en los niveles de eficiencia analizados dificultan una comparación directa y sencilla, nuestra cifra es mucho más alta que la prima de precio estimada en 2012.

En la mayoría de los países, la prima de precio por EE en lavadoras es sistemáticamente menor que en frigoríficos, aunque superior a la observada en otros electrodomésticos como aires acondicionados o purificadores de aire. Esto tiene sentido, ya que los consumidores pueden tener mayores incentivos (y estar más dispuestos a pagar) por la EE en electrodomésticos que usan con mayor frecuencia.

La información obtenida sobre la DAP por diferentes atributos también puede ser muy útil para los fabricantes de electrodomésticos. Nuestros resultados muestran que la reputación de la marca es el factor que mayor prima de precio aporta (49 %), mientras que las marcas consideradas de bajo prestigio afectan negativamente al precio. Esto concuerda con la literatura previa, que indica que la prima de precio de un electrodoméstico aumenta a medida que el posicionamiento de la marca mejora en el mercado.

Asimismo, determinadas características técnicas específicas tienen efectos significativos en el precio de las lavadoras:

- Atributos como el alto rendimiento de centrifugado (sdpA), el hecho de ser integrable y una mayor capacidad tienen un efecto positivo y significativo en el precio, con incrementos del 33 %, 31 % y 8,1 %, respectivamente.
- Por el contrario, las lavadoras de color blanco y aquellas que generan mayor ruido durante el centrifugado presentan efectos negativos en el precio, con una reducción del 15,5 % y 3,2 %, respectivamente.

Estos hallazgos tienen implicaciones claras para las políticas públicas.

En primer lugar, conocer con precisión la prima pagada en el mercado por el atributo de EE resulta fundamental para diseñar programas de subsidios y ayudas, que son ampliamente utilizados para fomentar la compra de electrodomésticos eficientes. Además, realizar estudios similares de forma periódica permitiría conocer la evolución de esta prima y evaluar las medidas y políticas implementadas en ese período. Esta información es esencial para determinar la efectividad de las políticas y esfuerzos para promover la EE.

En segundo lugar, el incremento de la prima de precio por lavadoras de alta EE en España (estimada en aproximadamente un 5 %) sugiere que los esfuerzos destinados a mejorar la información y la concienciación en torno a la EE y el cambio climático podrían estar surtiendo efecto, aumentando de manera significativa la disposición de los consumidores a pagar por electrodomésticos más eficientes.

Además, la etiqueta de EE está hoy ampliamente consolidada en el mercado de electrodomésticos; los consumidores la conocen y la valoran cada vez más a la hora de realizar sus compras. Por supuesto, también existen otros factores del lado de la oferta, como la introducción de nuevos estándares de EE, los avances tecnológicos y la evolución de los precios de la electricidad, que pueden contribuir a explicar este aumento en la DAP por productos eficientes. En cualquier caso, las cifras estimadas parecen coherentes con la mayoría de las investigaciones previas sobre primas de precio asociadas a la EE.

En general, todos los estudios tienden a encontrar una prima positiva por EE, aunque con variaciones en su magnitud en función del tipo de electrodoméstico, el país y el año analizado.

Estas diferencias en la prima de precio probablemente reflejan variaciones en las políticas nacionales de promoción de electrodomésticos eficientes, tales como campañas de información y sensibilización, subsidios e impuestos, además de otros factores del lado de la oferta, como el progreso tecnológico y los estándares de EE.

Asimismo, las diferencias en los precios de la electricidad pueden generar incentivos financieros distintos para la adopción de electrodomésticos más eficientes, según el país. Finalmente, las diferencias estimadas en las primas de precio entre países sugieren que factores culturales y medioambientales también podrían desempeñar un papel relevante en las decisiones de compra de los consumidores.

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ISSN: 2445-2726
Depósito Legal: M-7537-2016